APPENDIX A

DOCUMENTATION OF EMISSION ESTIMATION METHODOLOGIES FOR SOURCES OF 112(c)(6) POLLUTANTS:

POLYCYCLIC ORGANIC MATTER (POM),

2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (2,3,7,8-TCDD),

2,3,7,8-TETRACHLORODIBENZOFURAN (2,3,7,8-TCDF), AND

POLYCHLORINATED BIPHENYL COMPOUNDS (PCBs)

APPENDIX A

This appendix contains emissions estimate documentation for the extractable organic matter (EOM) category of polycyclic organic matter (POM), polychlorinated biphenyls (PCBs), 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), for 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF), and 2,3,7,8-TCDD Toxic Equivalents (TEQ). This appendix describes the approach and key assumptions adopted for each of the individual categories inventoried. For each source category, the following items are discussed:

- Pollutants for which reasonable emission estimates could be made for each source category;
- National activity levels and/or emissions estimates;
- Assumptions on processes and controls, primarily as they relate to the original test data on which the emission factors were based;
- Emission factors; and
- Assumptions for major/area determinations.

Data and information sources that were used in preparing the above items are referenced in each section. It should be noted that the detailed inventory development protocols for polycyclic aromatic hydrocarbons (PAHs) are presented in Appendix B. Both the 7-PAH and 16-PAH definitions of POM are covered. They are presented separately because all of the data were developed and drawn from another program, the Locating and Estimating (L&E) document for POM.

A.1 Municipal Waste Combustion

There are three main types of municipal waste incinerators in the United States: mass burn (MB), refuse derived fuel (RDF), and modular combustors (MOD). Mass burn combustors are the most common type of combustor, representing 54 percent of all municipal waste combustors (MWCs) in the United States, followed by modular facilities (32 percent) and RDF facilities (13 percent).[1]

According to the 1994 Maximum Achievable Control Technologies (MACT) Study there are 158 existing MWC facilities with design capacities above 38.6 tons/day. The facilities designed to burn less than 38.6 tons/day account for less than one percent of the total waste flow to MWC facilities.[2] Of the total MWC capacity in the United States, about 58 percent of municipal waste is treated in mass burn facilities, 29 percent in RDF-fired facilities, 9 percent in modular combustors, and 4 percent in other MWC designs.[3]

<u>Pollutants Addressed</u>

- EOM
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- PCBs

<u>National Activity Level/Emission Estimates</u>

The national dioxin/furan emissions estimates for MWCs were obtained directly from work done by EPA's Emission Standards Division (ESD) to support MACT standards for this source category. The estimates are based on dioxin data collected by the EPA during its "MWC Survey" in 1994. The dioxin emissions data that were collected were combined with MWC plant design data, plant annual utilization rate data, and flue gas flow rate conversion factors to calculate annual dioxin emission estimates. Although ESD calculated estimates for three different time periods (1993, 1995, and 2000), the 1993 data are presented here since this is the closest time period to the desired 112(c)(6) baseline date of 1990. A summary of the methods used to determine the estimates are provided here. More detailed information on the derivation of the estimates can be obtained from Reference 4.

Dioxin test results for 1993 were compiled from emission source tests performed between 1985 and 1993 (see Table A-1). In a limited number of cases, test results from 1994 on individual units were used if there were no changes in MWC unit operation or air pollution control device (APCD) configurations since 1993. Where the emission test date in the table is noted as 1985 through 1989, the data were gathered by OAQPS to develop the Subpart Ea new source performance standards and Subpart Ca emissions guidelines proposed for MWC's (December 1989). Where the emission test date is noted as 1990 through 1994, the data were gathered by OAQPS, or submitted to OAQPS, as part of one of the following efforts:

1. Data gathered by OAQPS to develop the revised new source performance standards and emission guidelines for MWC's proposed on September 20, 1994;

2. Data submitted to OAQPS in response to the "MWC Survey" of dioxin emissions; or

3. Data submitted to the docket (A-90-45) as public comments on the revised new source performance standards and emission guidelines proposed on September 20, 1994.

For facilities with dioxin test data, the following criteria were used to determine the most representative test results for each facility for 1993:

- For facilities with more than one test result, the most recent test was used. These results were chosen such that they were representative of plant operation at the end of 1993. Exceptions to this were in cases when two or more tests were conducted at a MWC over a relatively short period of time. Then, the average of these tests was used to represent the 1993 emissions.

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs

									Dioxin/Furans (ng/dscm @ 7% O_2)		
Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Total	TEQ[a]	Year
4	Huntsville Refuse-Fired Steam Fac.	AL	690	2	MB/WW	FF SD	2	345	3	0.080	1990
9	Commerce Refuse-to-Energy Fac.	CA	380	1	MB/WW	FF SD SNCR	1	380	10		1998
9	Long Beach (SERRF)	CA	1380	3	MW/WW	FF SD SNCR	1	460	4		1988
9	Stanislaus (Modesto)	CA	800	2	MB/WW	FF SD SNCR	1	400	32		1993
							2	400	9		1993
1	Bristol RRF	CT	650	2	MB/WW	FF SD	1	325	75	1.670	1990
							2	325	8	0.140	1990
1	Mid-Connecticut Project	CT	2000	3	RDF	FF SD	1	667	1		1988
1	Wallingford RRF	CT	420	3	MOD/EA	FF SD	1	140	178		1991
							2	140	50		1991
							3	140	47		1991
4	Dade Co. RRF	FL	3000	4	RDF	ESP	1	750	449		1990
4	Hillsborough Co. RRF	FL	1200	3	MB/WW	ESP	1	400	178		1994
4	McKay Bay REF	FL	1000	4	MB/WW	ESP	1	250	8533	265.000	1994
							3	250	893	21.000	1994
							4	250	2160	49.000	1994
4	Pasco Co. Solid Waste RRF	FL	1050	3	MB/WW	FF SD	1	350	11	0.190	1994
4	Wheelabrator Pinellas RRF	FL	3000	3	MB/WW	ESP	3	1000	3400[b]	71.800	1994
10	Honolulu Resource Recovery Venture	HI	2160	2	RDF	ESP SD	1	1080	10		1990
							2	1080	3		1990
10	Waipahu Incinerator	HI	600	2	MB/REF	ESP	1	300	5690		1994
5	Northwest WTE	IL	1600	4	MB/WW	ESP	2	400	65		1993

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs (Continued)

Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Dioxin/Furans (ng/dscm @ 7% O_2) Total	TEQ[a]	Year
5	Indianapolis RRF	IN	2362	3	MB/WW	FF SD	2	787	12	0.120	1989
							3	787	1	0.010	1993
1	Haverhill Lawrence RDF	MA	710	1	RDF	ESP FSI	1	710	136		1992
1	North Andover RESCO	MA	1500	2	MB/WW	ESP FSI	1	750	53		1989
1	SEMASS RRF	MA	2700	3	RDF	ESP SD	1	900	9		1989
						ESP SD	2	900	12		1989
1	Wheelabrator Millbury	MA	1500	2	MB/WW	ESP SD	2	750	59		1988
3	Hartford Co. WTE Fac.	MD	360	4	MOD/SA	ESP	1	90	300	5.580	1993
3	Pulaski	MD	1500	5	MB/REF	ESP	1	300	3313	37.000	1993
							2	300	3313	37.000	1993
							3	300	5894	85.200	1993
							4	300	5894	85.200	1993
							5	300	9045	104.000	1993
3	Southwest RRF (RESCO)	MD	2250	3	MB/WW	ESP	1	750	142	3.410	1993
							2	750	102	2.380	1993
							3	750	199		1993
1	Greater Portland Region RRF	ME	500	2	MB/WW	ESP SD	1	250	173		1987
1	Maine Energy Recovery (Biddeford)	ME	600	2	RDF	FF SD	1	300	4		1987
1	Penobscot Energy Recovery Comp.	ME	700	2	RDF	ESP	1	350	2		1988
5	Central Wayne Co. Sanitation Auth.	MI	500	2	RDF	ESP	1	250	383	12.200	1994
5	Clinton Township	MI	600	2	MB/REF	ESP	1	300	3254	55.800	1994
5	Greater Detroit RRF	MI	3300	3	RDF	ESP	1	1100	2851		1993
						FF SD	2	1100	2		1994

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs (Continued)

Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Dioxin/Furans (ng/dscm @ 7% O_2) Total	TEQ[a]	Year
5	Kent Co. WTE Fac.	MI	625	2	MB/WW	FF SD	1	312	5	0.090	1992
							2	312	12	0.310	1992
5	Hennepin Energy Recovery Facility	MN	1200	2	MB/WW	FF SD SNCR CI	1	600	1	0.030	1992
							2	600	2	0.020	1992
5	Olmstead WTE Facility	MN	200	2	MB/WW	ESP	1	100	219		1994
5	Perham Renewable RF	MN	114	2	MOD/SA	ESP	1	57	35		1994
5	Polk Co. Solid Waste Resource Recovery	MN	80	2	MOD/SA	ESP	1	40	269	8.990	1988
5	Pope-Douglas Solid Waste	MN	72	2	MOD/SA	ESP	2	36	446	7.440	1989
5	Ramsey-Washington	MN	720	2	RDF	ESP	2	360	31		1988
5	Red Wing Solid Waste Boiler Facility	MN	72	2	MOD/EA	ESP	1	36	489	13.300	1990
5	Western Lake Superior Sanit. Distr. (Duluth)	MN	260	2	RDF	VS	2	130	16		1992
5	Wilmarth Plant (Mankato)	MN	720	2	RDF	FF SD	1	360	27		1988
4	University City RRF	NC	235	2	MB/WW	ESP	2	118	579		1994
1	SES Claremont RRF	NH	200	2	MB/WW	FF DSI	1	100	38		1987
							2	100	32		1987
2	Camden RRF	NJ	1050	3	MB/WW	ESP SD	1	350	75		1992
2	Warren Energy RF	NJ	400	2	MB/WW	FF SD	1	200	8	0.180	1988
2	Adirondack RRF	NY	432	2	MB/WW	ESP SD	1	216	28		1992
							2	216	40		1992

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs (Continued)

Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Dioxin/Furans (ng/dscm @ 7% O_2) Total	TEQ[a]	Year
2	Babylon RRF	NY	750	2	MB/WW	FF SD	1	375	1		1991
							2	375	1		1993
2	Dutchess Co. RRF	NY	400	2	MB/RC	FF DSI	1	200	5		1989
							2	200	18		1989
2	Hempstead	NY	2505	3	MB/WW	FF SD	2	835	1	0.010	1993
2	Huntington RRF	NY	750	3	MB	FF SD SNCR	1	250	12	0.340	1993
							2	250	7	0.170	1993
							3	250	7	0.180	1993
2	Long Beach RRF	NY	200	1	MB/WW	ESP	1	200	709	13.700	1992
2	MacArthur WTE	NY	518	2	MB/RC	FF DSI	1	259	4		1993
							2	259	1		1993
2	Niagara Falls RDF WTE	NY	2200	2	RDF	ESP	1	1100	1217		1989
2	Oneida Co. ERF	NY	200	4	MOD/SA	ESP	1	50	462		1985
2	Oswego Co. WTE	NY	200	4	MPD/SA	ESP	1	50	386		1986
2	Westchester RESCO	NY	2250	3	MB/WW	ESP	1	750	183		1993
5	Akron Recycle Energy System	OH	1000	3	RDF	ESP	1	333	370[c]		1994
							2	333	370[c]		1994
5	City of Columbus SW Reduction Fac.	OH	2000	6	RDF	ESP	6	333	12998		1992
5	Montgomery Co. North RRF	OH	900	3	MB/RC/REF	ESP	1	300	5500[d]		1989
							2	300	5500[d]		1989
							3	300	8097	148.000	1994

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs (Continued)

Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Dioxin/Furans (ng/dscm @ 7% O_2) Total	TEQ[a]	Year
5	Montgomery Co. South RRF	OH	900	3	MB/RC/REF	ESP	1	300	5500[d]		1989
							2	300	5500[d]		1989
							3	300	5500[d]		1989
6	Walter B. Hall RRF	OK	1125	3	MB/WW	ESP	1	375	34		1986
							2	375	49		1987
10	Marion Co. WTE	OR	550	2	MB/WW	FF SD	1	275	1		1991
							2	275	4		1991
3	Delaware Co. RRF	PA	2688	6	MB/RC/WW	FF SD	1	448	2		1992
							2	448	4		1992
							3	448	10		1991
							4	448	11		1992
							5	448	4		1991
							6	448	10		1991
3	Harrisburg WTE	PA	720	2	MB/WW	ESP	2	360	1156	27.400	1994
3	Lancaster Co. RRF	PA	1200	3	MB/WW	FF SD	1	400	114	2.380	1993
							2	400	61	1.470	1993
							3	400	49	1.300	1993
3	York Co. RR Center	PA	1344	3	MB/RC/WW	FF SD	1	448	5		1993
							2	448	8		1993
							3	448	8		1993
4	Foster Wheeler Charleston RR	SC	600	2	MB/WW	ESP SD	2	300	44		1990
4	Nashville Thermal Transfer Corp.	TN	1050	3	MB/WW	ESP	3	350	143		1994

Table A-1

Test Data Used for 1993 National Dioxin Estimates for MWCs (Continued)

									Dioxin/Furans (ng/dscm @ 7% O_2)		
Region	Unit Name	State	Total Plant Capacity	Number of Units	Combustor Type	Air Pollution Control Devices	Unit Number	Unit Capacity	Total	TEQ[a]	Year
3	Alexandria/Arlington RRF	VA	975	3	MB/WW	ESP DSI CI	1	325	14[e]		1987
							3	325	18[e]		1993
3	Hampton (NASA) Refuse-fired Steam Gen.	VA	200	2	MB/WW	ESP	1	100	102	2.520	1992
3	Harrisonburg RRF	VA	100	2	MB/WW	ESP	1	50	8459	115.000	1994
3	I-95 Energy RRF (Fairfax)	VA	3000	4	MB/WW	FF SD	1	750	9	0.230	1993
							2	750	6	0.170	1993
							3	750	8	0.200	1993
							4	750	7	0.150	1993
3	Norfolk Navy Yard	VA	2000	4	RDF	ESP	1	500	21129	429.000	1993
							2	500	32237	595.000	1993
							3	500	42955	1500.000	1994
							4	500	26360	800.000	1993
5	LaCrosse Co.	WI	400	2	RDF/FB	DSI EGB	1	200	63		1993
5	St. Croix Co. WTE Fac.	WI	115	3	MOD/SA		1	38	8		1988

[a]Dioxin concentrations are listed both in units of ng/dscm total mass and ng/dscm TEQ where both were available. The TEQ concentration data were used for TEQ emissions calculations where TEQ data were available, and where TEQ data were not available a conversion ratio of 50:1 (total:TEQ) was used to convert the total mass data to TEQ.
[b]Pinellas data are average of three separate tests done during one year.
[c]Akron data were from 1994 test, and assumed to be representative of Akron pre-1994. MWC Survey discussion indicates that high ESP temperature was reported.
[d]Montgomery North/South data (except for Unit No. 3 at North) are an average value determined based on numerous tests.
[e]Alexandria data in MWC survey were from a test run without carbon injection. Since the unit has carbon injection, an additional reduction of 75% was assumed.

- At facilities with multiple units where not all units were tested, an average of the test results from the tested units was used as a representative value for the untested units.

Test results were obtained for approximately 55 percent of the domestic MWC's. For the other 45 percent, a set of default values was created and used to estimate dioxin concentrations. The set of default values was compiled from test data, AP-42 emission factors, and from the EPA document EPA-450/3-89-27e "Municipal Waste Combustors - Background Information for Proposed Guidelines for Existing Facilities" (this document presented the results of a study on APCD retrofits on MWC units). Default values were generated for every MWC combustor type and APCD configuration for which a default value was needed. Test data available to OAQPS, as of January 15, 1995, were organized into groups based on MWC combustor type and APCD configurations and averaged. These averages were designated as the default values for the corresponding combustor/APCD configurations. For the combustor/APCD configurations where there were no test data available, default values were obtained from the MWC section in AP-42 (section 2.1), or from EPA document EPA-450/3-89-27e. A summary of the default values is given in Table A-2.

To estimate annual emissions, a capacity factor for each unit is needed. This factor represents the percentage of operational time a plant has operated during one year. By using the capacity factor and unit capacity, the annual throughput (combustion) of MSW or RDF can be calculated. Some facilities provided data to OAQPS on the tonnage of municipal waste burned in year 1993. For these facilities, a capacity factor was estimated by dividing the tonnage burned in one year by the unit’s rated yearly capacity and was used for the 1993 emissions calculation. For most units, however, the capacity factors used were default values taken from EPA document EPA-450/3-89-27e. For all units except modular/starved-air combustors, the default capacity factor was 91 percent (0.91). For modular/starved-air units, the default capacity factor was 74 percent (0.74).

Table A-2

Default Dioxin/Furan Emission Levels From MWC Configurations[a]

Combustor Type	APCD Type	Average Dioxin Value (ng/dscm @ 7% O_2, total mass)
MB/WW	ESP*	222
	DSI/ESP	60
	DSI/FF	35
	SD/ESP	70
	SD/FF	16
RDF (all except FB)	ESP*	240
	DSI/FF	17
	SD/ESP	9
	SD/FF	8
RDF/FB	DSI/EGB	63
MB/RC/WW	ESP*	400
	DSI/ESP	100
	DSI/FF	7
	SD/ESP	40
	SD/FF	5
MB/REF	ESP*	500
	DSI/ESP	57
	DSI/FF	17
	SD/ESP	40
	SD/FF	5
MOD/SA	Uncontrolled	300
	ESP*	288
	DSI/ESP	98
	DSI/FF	8
	SD/ESP	40
	SD/FF	5
MOD/EA	Uncontrolled	200
	ESP*	468
	DSI/ESP	50
	DSI/FF	8
	SD/FF	92

[a]Values presented in this table are averages of available data for various combustor type/APCD type combinations. Values were estimated based on a compilation of the MWC survey data, background information for the 1991 and 1994 MWC rulemakings, public comments received on the 1994 MWC rulemaking, and AP-42 (4th edition). None of the data listed provides credit for supplemental dioxin control (polishing) by CI. The use of CI typically reduces dioxin emissions by an additional 75 percent or more. (See Air Docket A-90-45, items VI-B-013 and VI-B-014).

* ESP operated at less than 440 ^oF.

APCD = air pollution control device
DSI = duct sorbent injection
EA = excess air
EGB = electrified gravel bed
ESP = electrostatic precipitator
FB = fluidized bed
FF = fabric filter
MB = mass burn
MOD = modular
RC = rotary combustor
RDF = refuse derived fuel
REF = refractory wall
SA = starved air
SD = spray dryer
WW = waterwall

For many test results and for all dioxin default concentrations, TEQ concentrations were not available. Similar to the development of the default dioxin concentrations, a defaulttotal mass-to-TEQ ratio was also developed. Test results from units for which there were both total mass and TEQ results available were used to develop a default ratio of total dioxin concentration to TEQ concentration. The total:TEQ ratios from these units were averaged, resulting in a default ratio of 50:1. This ratio was used for estimating TEQ emissions for all sources where TEQ test data were not available.

The F_d factor is a standard conversion factor used in combustion calculations to determine exhaust flowrates based on heat input. Full documentation of F_d factors is given in 40 CFR 60, Appendix A, Method 19. The specific F_d factor for municipal waste combustion, given by Method 19, is 9,570 dry standard cubic feet of flue gas per million Btu (dscf/MMBtu) of municipal waste combustion. This flow rate is based on 0 percent excess O_2 in the flue gases.

Average heating values for fuels derived from municipal wastes are given in the Refuse Combustion section of AP-42 (section 2.1). For unprocessed municipal solid waste (MSW), the heating value is 4,500 Btu per pound. For RDF, the heating value is 5,500 Btu per pound. The heating value for RDF is higher than general MSW because RDF goes through some degree of pre-processing to remove non-combustible materials.

The first step in calculating annual dioxin emissions from MWC's was to calculate the emissions from individual units. This task was accomplished with plant-specific information such as dioxin emission concentration, unit size, unit capacity factor, fuel heating value, and the F_d factor.

The following equation was used to convert dioxin stack concentrations (total and TEQ) to grams per year (g/yr) emitted:

$$\text{Emissions}\left(\frac{g}{yr}\right) = \frac{C \text{ x } V \text{ x } T \text{ x } CF}{10^9}$$

where:

Emissions	=	Annual dioxin emissions (g/yr)
C	=	Flue Gas Dioxin Concentration (ng/dscm @7 percent O_2)
V	=	Volumetric Flow Factor (dscm @7 percent O_2/ton waste fired)
T	=	Tons of MSW burned/year (@100 percent capacity for 365 days/year)
CF	=	Capacity Factor (unitless)

The volumetric flow factor (V) is calculated as follows:

$$V = \frac{F_d \text{ x } HV \text{ x } 2000 \text{ x } 10^{-6}}{35.31} \text{ x } \frac{20.9}{20.9-7}$$

where:

$$HV = \text{Heating Value } (4{,}500 \ \frac{Btu}{lb} \text{ for MSW and } 5{,}500 \ \frac{Btu}{lb} \text{ for RDF})$$

$$V = \frac{\left(9{,}570 \ \frac{\text{dscf @ 0\% } O_2}{\text{MMBtu}}\right)\left(4{,}500 \ \frac{Btu}{lb}\right)\left(2{,}000 \ \frac{lb}{ton}\right)}{\left(35.31 \ \frac{dscf}{dscm}\right)\left(10^6 \ \frac{Btu}{MMBtu}\right)} \text{ x } \left(\frac{20.9}{20.9 - 7}\right)$$

$$= 3{,}670 \ \frac{\text{dscm @ 7\%} O_2}{\text{ton MSW}} \text{ for non-RDF units}$$

$$V = \frac{\left(9{,}570\ \frac{\text{dscf @ 0\% } O_2}{\text{MMBtu}}\right)\left(5{,}500\ \frac{\text{Btu}}{\text{lb}}\right)\left(2{,}000\ \frac{\text{lb}}{\text{ton}}\right)}{\left(35.31\ \frac{\text{dscf}}{\text{dscm}}\right)\left(10^6\ \frac{\text{Btu}}{\text{MMBtu}}\right)} \times \left(\frac{20.9}{20.9 - 7}\right)$$

$$= 4{,}457\ \frac{\text{dscm @ 7\%} O_2}{\text{ton RDF}} \text{ for RDF units}$$

Example Calculation

For a mass burn/waterwall (non-RDF) unit, rated at 500 tons/day capacity (365,000 tons/yr), with a dioxin concentration of 10 ng/dscm (total mass) @7 percent O_2, annual dioxin emissions are calculated to be:

$$\frac{\left(\frac{10\ \text{ng}}{\text{dscm}} \text{ @ 7\% } O_2\right)\left(3{,}670\ \frac{\text{dscm @ 7\% } O_2}{\text{ton}}\right)\left(182{,}500\ \frac{\text{ton}}{\text{yr}}\right)(0.91)}{10^9\ \frac{\text{ng}}{\text{g}}}$$

= 6.1 g dioxin/yr (total mass), or

= 6.1/50 = 0.12 g dioxin/yr (TEQ)

Dioxin/furan emission estimates from municipal waste combustors are currently under review and evaluation by the U.S. EPA. These values are subject to possible change due to these evaluations. If the current review indicates a change is necessary, this report will be modified accordingly.

Emission estimates for PCBs and EOM were calculated based on the combination of emission factors and activity data for the amount of waste processed. These data are presented in this section. The ESD MACT work did not address EOM or PCBs.

Assumptions on Processes and Control Levels

Emissions from MWCs are controlled by electrostatic precipitators (ESPs), spray dryers, and fabric filters. According to the MACT study, more ESPs are used by MWCs (44 percent) to control emissions than any other control devices. The emission factors for EOM and PCBs used to determine 1990 national emissions reflect municipal waste combustor performance with an ESP in place.

Emission Factors

The EOM emission factor presented below is based on emissions testing of a MB incinerator.[5] The combustion units were of the stoker type and ESP controls were installed on the units. The Municipal Waste Combustion Study, Emission Database for Municipal Waste Combustors, provides emission data for PCBs.[6] The PCB emission factor was derived from three emission tests at a MB facility with an ESP.[7]

Table A-3 lists the emission factors for EOM and PCBs that were used to develop the national emissions estimate for municipal waste combustion.

TABLE A-3. MUNICIPAL WASTE COMBUSTION EMISSION FACTORS FOR EOM AND PCBs

Pollutant	Emission Factor	Units
EOM	0.0114	lb/ton of waste burned
Total PCBs	5.5×10^{-6}	lb/ton of waste burned

Major/Area Source Assumptions

Approximately 95 percent of all municipal waste incinerators are major sources due to hydrogen chloride (HCl) emissions. This assumption is based on data contained in References 8 and 9.

REFERENCES FOR MUNICIPAL WASTE COMBUSTION

1. U.S. Environmental Protection Agency. January 1992. Economic Impact and Preliminary Regulatory Impact Analysis for Proposed MACT-Based Emission Standards and Guidelines for Municipal Waste Combustors. EPA-450/3-91-029. Office of Air and Radiation. p. 3-9.

2. U.S. Environmental Protection Agency. January 1992. Economic Impact and Preliminary Regulatory Impact Analysis for Proposed MACT-Based Emission Standards and Guidelines for Municipal Waste Combustors. EPA-450/3-91-029. Office of Air and Radiation. p. 3-8.

3. U.S. Environmental Protection Agency. April 1989. Locating and Estimating Air Toxics Emissions from Municipal Waste Combustors. EPA-450/2-89-006. Office of Air and Radiation. p. 3-1.

4. U.S. Environmental Protection Agency. June 1996. National Dioxin Emission Estimates for Municipal Waste Combustors. Emission Standards Division, Research Triangle Park, North Carolina.

5. Watts, Randall R., et. al. 1992. Development of Source Testing, Analytical, and Mutagenicity Bioassay Procedures for Evaluating Emissions from Municipal and Hospital Waste Combustors. Environmental Health Perspectives, Volume 98. pp. 227 - 234.

6. U.S. Environmental Protection Agency. June 1987. Municipal Waste Combustion Study, Emission Database for Municipal Waste Combustors. EPA-530/SW-87-021b. Office of Air and Radiation. p. 7-76.

7. U.S. Environmental Protection Agency. June 1987. Municipal Waste Combustion Study, Emission Database for Municipal Waste Combustors. EPA-530/SW-87-021b. Office of Air and Radiation. p. 7-158.

8. Memorandum to Walt Stevenson, EPA/SDB, from Denise Fenn and Kris Nebel, Radian Corporation. August 20, 1992. Information on the Municipal Waste Combustion Database.

9. U.S. Environmental Protection Agency. August 1989. Municipal Waste Combustors - Background Information for Proposed Guidelines for Existing Facilities. EPA-450/3-89-27e. pp. 6-66 - 6-67.

A.2 Medical Waste Incineration

The Resource Conservation and Recovery Act (RCRA), 1976, defines medical waste as "...any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in production or testing of biologicals." The incineration of medical waste occurs at: hospitals, laboratories, veterinary facilities, nursing homes and at commercial incinerators. (This definition does not include biological incinerators at crematories and animal shelters. The biological incinerators are treated as a separate source category under Section A.3.) Hospital incinerators are the most common type of medical incinerator and burn more waste than other medical waste incinerator types.[1]

Medical waste incinerators vary widely in capacity. Incinerators operate continuously or intermittently, based on waste loading rates and incinerator type.

Pollutants Addressed

- EOM
- 2,3,7,8 - TCDD
- 2,3,7,8 - TCDF
- 2,3,7,8-TCDD TEQ
- Total PCBs

National Activity Levels/Emission Estimates

Three types of incinerators are used to burn medical wastes: controlled air, excess air, and rotary kiln. About 95 percent of these are controlled air incinerators.[2] Using facility capacities, it was estimated that about 1.57 x 10^6 metric tons of medical waste were incinerated in 1990.[3] These activity data and the subsequent information on control status and emission factors were used to calculate estimates for EOM and PCB emissions. All estimates for dioxin/furans were based on direct estimates from EPA regulatory programs as explained in the following paragraphs.

The national dioxin/furan emissions estimates for medical waste incinerations (MWIs) were obtained directly from work done by EPA's Emission Standards Division (ESD) to support Maximum Achievable Control Technology (MACT) standards for this source category. The starting point for the national estimates is a 1995 inventory of existing MWIs, which includes for each MWI the location, type (batch or non-batch), and the design capacity of the unit. The 1995 inventory was adjusted to create a 1990 inventory of national emissions for MWIs. A summary of the methods used to determine the estimates are provided here. More detailed information on the derivation of the estimates can be obtained from Reference No. 4.

The estimates of the nationwide dioxin emissions were developed based on an inventory of existing MWI's in 1995. The 1995 inventory was adjusted to create both a 1990 inventory and a year 2002 inventory. The information used to develop the inventories was taken from a number of sources including a listing of MWI's prepared by the American Hospital Association (AHA), state air permits gathered by EPA, and a survey of MWI's in California and New York conducted by EPA in 1995. The AHA inventory was itself taken from two sources; an EPA "Locating and Estimating" document and a vendor listing. Once this information was compiled, the inventory was reviewed and modified based on updates from state surveys, commercial sources, and MWI vendors.

The capacity of each MWI was provided in the inventory. The capacities for the continuous and intermittent MWI's in the inventory were expressed in terms of an hourly charging rate in pounds per hour (lb/hr). Batch MWI capacities were provided in pounds per batch (lb/batch). Therefore, batch MWI's were evaluated separately from the continuous and intermittent MWI's and the batch capacities were not converted to hourly burning rates.[4]

Also included in the inventory was the applicable state particulate matter (PM) emission limit for each MWI. The AHA listing of MWI's and the state air permits included PM limits for each MWI. Where PM limits were not listed, limits were applied based on State regulatory requirements using the same methods described in the MACT floor analysis for the proposed standards. PM limits could be used to estimate the type of emission control at MWI's for which the control was not identified for the MWI.

Nationwide MWI emissions were calculated by first calculating MWI emissions on a unit specific basis using the MWI inventory and considering unit specific parameters. Actual emission control data was used where available and was estimated when not available. In calculating emissions and estimating operating parameters, there are three distinct types of MWI's as follows: batch, intermittent, and continuous. The difference in these three MWI types is in the methods of charging waste to the MWI and removing ash from the primary chamber of the MWI. Continuous MWI's, which are the largest of the three types, have mechanical ram feeders and continuous ash removal systems. These features allow the unit to operate 24 hours per day for many days at a time. Most intermittent MWI's also have mechanical ram feeders that charge waste into the primary chamber. However, intermittent MWI's do not have an automatic ash removal system, and can only be operated for a limited number of hours before the unit must be shut down for ash removal. In batch MWI's, all of the waste to be burned is loaded into the primary chamber and, once the burning cycle begins, no additional waste is loaded. After the burn cycle for a batch unit is complete and the unit has cooled down, the ash is removed manually. In the inventory of existing MWI's used to estimate the nationwide dioxin emissions, a differentiation was made between batch and nonbatch (continuous and intermittent) MWI's. However, no distinction was made between continuous and intermittent MWI's in the final inventory.[4]

The hours of operation were estimated for each MWI type in the inventory in order to determine the annual waste incinerated. The hours of operation were defined as the hours during which the MWI combusts waste.

For batch MWI's, it is estimated that a typical MWI charges waste 160 times per year (i.e., 160 batches/yr; 3 batches per week). The amount of waste burned each year in a batch unit and the yearly emissions produced depend primarily on the unit capacity and the annual number of batches. Because of this relationship, it was unnecessary to determine the actual hours of operation for batch MWI's.

For continuous and intermittent MWI's, operating hours were estimated for three size categories ($\leq$500, 501 to 1,000, and >1,000 lb/hr). All MWI's with capacities less than 500 lb/hr were assumed to be intermittent MWI's. The waste charging hours for intermittent MWI's with capacities less than 500 lb/hr were estimated at 1,250 hours per year (hr/yr). Since the inventory does not indicate whether an MWI is continuous or intermittent, a ratio of about 3 to 1, intermittent to onsite continuous, was used to estimate the hours of operation for onsite continuous and intermittent MWI's with capacities greater than 500 lb/hr. The average operating hours for continuous MWI's in the 501 to 1,000 lb/hr size category was 2,916 hr/yr and the average charging hours for intermittent MWI's in this size category was 1,500 hr/yr. The weighted average of the charging hours for the combined continuous and intermittent MWI's was determined as follows:

$$(1{,}500 \text{ hr/yr} \times 0.77) + (2{,}916 \text{ hr/yr} \times 0.23) = 1{,}826 \text{ hr/yr}$$

Large MWI's with design capacities greater than 1,000 lb/hr were estimated to operate 2,174 hr/yr and all commercial MWI's were estimated to operate 7,776 hr/yr. A summary of the waste charging hours for the continuous and intermittent MWI's is presented below.[4]

MWI Capacity	Charging Hours (hr/yr)	Capacity Factor (%)
<500 lb/hr	1,250	29
501-1,000 lb/hr	1,826	33
>1,000 lb/hr	2,174	40
All commercial MWI's	7,776	89

NOTE: "Capacity factor" means ratio of tons of waste actually burned per year divided by the tons of waste that could be burned per year had the unit ben operating at full capacity.

A capacity factor represents the percentage of operational time a MWI has operated in 1 year. Capacity factors were calculated for each MWI size category based on the ratio of the actual annual charging hours to the maximum annual charging hours. For intermittent MWI's, the maximum annual charging hours were estimated to be 4,380 hr/yr. This is based on 12 charging hours per day and 365 days per year because intermittent MWI's must shut down for daily ash removal. The maximum annual charging hours for continuous MWI's were estimated to be 8,760 hr/yr based on 24 charging hours per day and 365 days per year. All commercial MWI's were assumed to be continuous units. The maximum annual charging hours for onsite MWI's with capacities greater than 500 lb/hr were estimated to be 5,475 hr/yr, based on the 3 to 1 ratio of intermittent to onsite continuous MWI's discussed previously. The calculated capacity factors for each MWI size category are shown in the box above.

Waste charging rates measured during emissions tests show the average hourly charging rates to be about two-thirds of the MWI design rates specified by incinerator manufacturers. Therefore, waste was assumed to be charged at two-thirds of the MWI design capacity. Using the operating hours per year (or number of batches per year for batch units) and the corrected waste charge rate (tow-thirds of the design rate), the amount of waste burned annually was determined for each MWI.

Actual emission control data was used where available and was estimated when necessary. When emission control system type was unknown it was estimated based on (1) the average PM emission rates for the different types of emission controls and (2) the PM limit to which the MWI is subject. For example, the average PM emission rate for intermittent and continuous MWI's with 1/4-second combustion control was estimated from test data to be 0.30 gr/dscf. Thus, any MWI with a PM emission limit greater than 0.30 gr/dscf was assumed to have a 1/4-second combustion system. The PM emission limit ranges for all of the emission controls are shown below.

PM Emission Limit (gr/dscf at 7% O_2)	Assumed Level of Emission Control
Intermittent and continuous MWI's	
$\geq$0.3	1/4-sec combustion control
0.16 $\leq$ x <0.3	1-sec combustion control
0.10 $\leq$ x 0.16	2-sec combustion control
0.015 < x <0.10	Wet scrubbers
$\leq$ 0.015	Dry scrubbers
Batch MWI's	
$\geq$ 0.079	1/4-sec combustion control
0.042 $\leq$ x < 0.079	1-sec combustion control
0.026 $\leq$ x <0.042	2-sec combustion control
<0.026	Wet scrubbers

An analysis of EPA-sponsored emission test data showed a direct relationship between the CDD/CDF emissions on a "total" dioxin basis and a "TEQ" basis. For total CDD/CDF emissions greater than 150 nonograms per dry standard cubic meter (ng/dscm), the ratio of total CDD/CDF emissions to the TEQ emissions was 48:1. For total CDD/CDF emissions less than 150 ng/dscm, the ratio was 42:1. These ratios were used with test data on total CDD/CDF emissions to develop TEQ emission factors for each type of emission control. The resulting dioxin and TEQ emission factors are shown in Table A-4.

Table A-4

Total Dioxin and TEQ Emission Factors

Type of Emission Control	TEQ Factors, lb/TEQ Dioxin/lb Waste	Dioxin Factors, lb Total Dioxin/lb Waste
1/4-sec combustion control	3.96×10^{-9}	1.94×10^{-7}
1-sec combustion control	9.09×10^{-10}	4.45×10^{-8}
2-sec combustion control	7.44×10^{-11}	3.65×10^{-9}
Wet scrubbers	1.01×10^{-11}	4.26×10^{-10}
Dry scrubbers no carbon	7.44×10^{-11}	3.65×10^{-10}
Dry scrubbers with carbon	1.68×10^{-12}	7.04×10^{-11}
Fabric filter/packed bed	6.81×10^{-10}	3.34×10^{-8}

In combination with the MWI parametric data, control technology data, and emission factors the following equation was used to calculate the annual dioxin emissions from each MWI in the MWI inventory:

$$\text{Emissions} = (C \times H \times C_1) \times F \times Q$$

Where:

Emissions	=	Annual dioxin emissions, g/yr
C	=	MWI capacity, lb/hr
H	=	Charging hours, hr/yr
C_1	=	Ratio of waste charging rate to design capacity, 2:3
F	=	Emission factor for the appropriate level of control (lb dioxin/lb waste charged), and
Q	=	Conversion factor for pounds to grams, 453.6 grams/lb.

The number of MWI's in each state as of 1990 was determined by first starting with the MWI's listed in the 1995 inventory and then adjusting it by adding MWI's that "shut down" in the

1990 to 1995 time period. The adjustment in MWI population occurred in states that adopted "stringent" MWI rules in the 1990-1995 time period that resulted in MWI closure because of economic considerations.

An assessment was made of the states that have adopted "stringent" air emissions regulations applicable to MWI's between 1990 and 1995. For the purpose of this study" stringent" regulations are those that require all size of MWI's to meet an emission limit of less than 0.08 grains per dry standard cubic foot (gr/dscf) of PM. A PM emission limit of less than 0.08 gr/dscf usually requires the retrofit of an add-on air pollution control device (APCD) which, because of costs, generally leads to a shut-down of MWI's.

The greatest change in the nationwide dioxin emissions from MWI's between 1990 and 1995 is due to the shut-down of MWI's and not from retrofit of air pollution control. In California, New Mexico, New York, Oregon, Washington, Wisconsin, Florida, and South Dakota, MWI shut-downs were experienced at most facilities that were operating in-state prior to 1990. These are referred to here as "regulated" states. All other states are referred to as "unregulated" states. The "unregulated" states are those that either have not implemented "stringent" regulations on MWI's or that have not experienced many MWI shut-downs since 1990.

The number of MWI's in the unregulated states in 1990 was assumed to be the same as the number of MWI's in the 1995 inventory because the unregulated states are unlikely to have experienced shut-downs in the 1990-1995 time period. For the regulated states, the number of MWI's that existed in 1990 was estimated using information from MWI vendor and state listings of MWI's.

The next step in calculating emissions was to determine the amount of waste burned in MWI's in 1990 for each state. For the unregulated states, the amount of waste burned in 1990 was assumed to be the same as the current amount of waste burned in 1995, which was obtained directly from the inventory. In each of the regulated states, the ratio of the 1990 number of

MWI's to the 1995 number of MWI's was applied to the current total waste burned to obtain the 1990 total waste burned. For regulated states with no MWI's in the 1995 inventory, the 1990 amount of waste burned was approximated using the amount of waste burned from unregulated states with the same number of 1990 MWI's. In cases where there were no unregulated states with the same number of MWI's, the amount of waste burned in a regulated state not appearing in the inventory was approximated by summing the waste burned from several unregulated states, that together have the same number of 1990 MWI's as the regulated state.[4]

Dioxin emission factors were applied to the 1990 total waste burned in each regulated state to obtain the 1990 emissions. The total mass dioxin emission factor used for this estimate was 2.56×10^{-8} lb dioxin/lb waste combusted, which is a weighted emission factor that accounts for continuous, intermittent, and batch MWI's of all sizes. This emission factor was developed by dividing the dioxin emitted yearly from each uncontrolled (i.e., no gas scrubber system) MWI in the current inventory by the total waste burned yearly in each uncontrolled MWI. Similarly, the TEQ emission factor that accounts for all sizes and types of uncontrolled MWI's used to estimate the 1990 TEQ emissions was 5.33×10^{-10} lb TEQ dioxin/lb waste combusted. Uncontrolled emission factors were used to predict the 1990 dioxin emissions because MWI's that have shut down due to regulations are likely to have been uncontrolled.[4]

The sum of the 1990 emissions in the unregulated states was added to the sum of the 1990 emissions from the regulated states to obtain the nationwide 1990 dioxin emissions estimate of 600 grams (1.32 lb). This estimate is based on 3,400 facilities in operation and 1.73 million tons of waste incinerated.[3] Also, TEQ emissions are estimated to be 0.33 lb in 1995.[4]

Assumptions on Process and Control Levels

Medical waste incinerators have primarily been operated without add-on pollution control devices; only 2 percent currently utilize emission controls.[2] The EOM and PCB emission factors used to develop national emissions will be based on emissions data from uncontrolled incinerators.

Emission Factors

Table A-5 lists the PCB and EOM emission factors that were used to develop the national emissions estimates for medical waste incineration. The emission factor for PCB is for uncontrolled medical waste incinerators and was obtained from the AP-42 chapter on Medical Waste Incineration.[5] The EOM emission factor represents an uncontrolled medical waste incinerator and was calculated from test data in the Health Effects and Research Laboratory (HERL) study.[6]

TABLE A.5. MEDICAL WASTE INCINERATION EMISSION FACTORS FOR EOM AND PCBs

Pollutant	Emission Factor	Units
EOM	1.78×10^{-2}	lb/ton of waste burned
Total PCB	4.65×10^{-5}	lb/ton of waste burned

Major/Area Source Assumptions

Although most medical waste incinerators are operated without add-on air pollution control devices, most are too small to be major sources. Hydrogen chloride (HCl) is one of the pollutants emitted in large quantities from medical waste incinerators.[7] Average facility capacities[1] and an HCl emission factor for a controlled air incinerator without add-on pollution controls[2] were used to estimate that approximately 85 percent of medical waste incinerators are area sources. The remaining 15 percent are estimated to be major sources since these facilities have the potential to emit 10 tons per year of HCl.

REFERENCES FOR MEDICAL WASTE INCINERATION

1. U.S. Environmental Protection Agency. July 1994. Medical Waste Incinerators - Background Information for Proposed Standards and Guidelines: Industry Profile Report for New and Existing Facilities. EPA-453/R-94-042a.

2. Emission Factor Documentation for AP-42 Section 2.6, Medical Waste Incineration. July 1993. p. 2.6-1.

3. Telephone conversation between Rick Copeland (U.S. Environmental Protection Agency) and Jack Johnson (Eastern Research Group, Inc.) January 7, 1997.

4. U.S. Environmental Protection Agency. June 1996. National Dioxin Emissions from Medical Waste Incinerators. Docket No. A-91-61, Item IV-A-007. Emission Standards Division. Research Triangle Park, North Carolina.

5. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

6. Emission Factor Documentation for AP-42 Section 2.6, Medical Waste Incineration. July 1993. p. 2.6-12.

7. Watts, Randall R., et. al. 1992. Development of Source Testing, Analytical, and Mutagenicity Bioassay Procedures for Evaluating Emissions from Municipal and Hospital Waste Combustors. Environmental Health Perspectives, Volume 98. pp. 227 - 234.

A.3 Other Biological Waste Incineration

This source category includes the burning of biological waste from crematories and animal shelters. Most crematories operate as batch incinerators, and animal shelters have intermittent incinerators.[1]

Pollutants Addressed

- EOM
- 2,3,7,8 - TCDD
- 2,3,7,8 - TCDF
- 2,3,7,8-TCDD TEQ
- Total PCBs

National Activity Level/Emissions Estimates

There are approximately 395 human crematories and 1,700 animal shelters with cremation devices in the United States.[1] Using model facility information and typical charging rates developed as background information for medical waste incinerator standards and guidelines, it was determined that these incinerators burn approximately 107,000 metric tons of biological waste per year.[2]

Assumptions on Processes and Control Levels

Like medical incinerators, crematories, and animal shelters are assumed to operate primarily without add-on pollution control devices. The emission factors used to develop national emissions will be based on emissions data from uncontrolled medical waste incinerators.

Emission Factors

Table A-6 lists the emission factors for each pollutant that were used to develop the national emissions estimates for other biological incineration. The emission factor for PCB is for uncontrolled medical waste incinerators and was obtained from the AP-42 chapter on Medical Waste Incineration.[3] The EOM emission factor represents an uncontrolled medical waste incinerator and was calculated from test data in the HERL study.[4] The emission factor for 2,3,7,8-TCDD TEQ was estimated based on information presented in a report by the EPA's Office of Health and Exposure Assessment.[5]

TABLE A-6. OTHER BIOLOGICAL WASTE INCINERATION EMISSION FACTORS

Pollutant	Emission Factor	Units
EOM	1.78×10^{-2}	lb/ton of waste burned
Total PCB	4.65×10^{-5}	lb/ton
2,3,7,8-TCDD TEQ	2.72×10^{-6}	lb/ton

Major/Area Source Assumptions

It was assumed for purpose of this analysis that 100 percent of biological incinerators are area sources.

REFERENCES FOR OTHER BIOLOGICAL WASTE INCINERATION

1. Midwest Research Institute. July, 1994. Medical Waste Incinerators-Background Information for Proposed Standards and Guidelines: Environmental Impacts Report for New and Existing Facilities.

2. U.S. Environmental Protection Agency. June 1996. Mercury Study Report to Congress, Volume II: An Inventory of Anthropogenic Mercury Emissions in the United States. SAB Review Draft. EPA-452/R-96-001b. Office of Air Quality Planning and Standards and Office of Research and Development, Research Triangle Park, North Carolina.

3. Emission Factor Documentation for AP-42 Section 2.6, Medical Waste Incineration. July 1993. p. 2.6-12.

4. Watts, Randall R., et. al. 1992. Development of Source Testing, Analytical, and Mutagenicity Bioassay Procedures for Evaluating Emissions from Municipal and Hospital Waste Combustors. Environmental Health Perspectives, Volume 98. pp. 227 - 234.

5. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC.

A.4 Sewage Sludge Incineration

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF
- Total PCBs

National Activity Level/Emission Estimates

In 1990, there were an estimated 174 operating sewage sludge incinerators in the United States.[1] In 1995, only 143 facilities were operating. More than 80 percent of the facilities in 1990 were multiple hearth incinerators.[2] In 1992, approximately 8.65 x 10^5 metric tons of dry sewage sludge were incinerated.[1]

Assumptions on Process and Control Levels

Multiple hearth sewage sludge incinerator emissions are usually controlled by a venturi scrubber or an impingement tray scrubber.[3]

Emission Factors

The emission factors for dioxin and furan emissions are for a multiple hearth incinerator with an impingement tray scrubber in place.[4] As noted in the text of this report, the EPA is currently reviewing the dioxin/furan emission estimates for this source category; these estimates are subject to possible revision.

The PCB emission factor is based on source measurements conducted at five multiple hearth incinerators controlled with wet scrubbers.[5] Table A-7 lists the emission factors for each pollutant that were used to develop the national emissions estimate for sewage sludge incineration.

TABLE A-7. SEWAGE SLUDGE INCINERATION EMISSION FACTORS FOR PCBs AND TCDD TEQ

Pollutant	Emission Factor	Units
2,3,7,8-TCDD TEQ	5.57×10^{-8}	lb/ton dry sludge
Total PCBs	1.08×10^{-5}	lb/ton dry sludge

<u>Major/Area Source Assumptions</u>

It is assumed that all sewage sludge incinerators are area sources located in urban areas. This assumption takes into account the other emissions that can occur at waste treatment facilities such as hazardous air pollutants (HAPs) from aeration basins, and metals, chlorine, and chloroform emissions from incineration. Emission estimates developed for a typical sewage sludge incinerator using conservative assumptions found that HAP emissions are far below 25 tons per year.

REFERENCES FOR SEWAGE SLUDGE INCINERATION

1. Federal Register. February 19, 1993. Standards for the Use or Disposal of Sewage Sludge; Final Rules. F.R. 58: 9248-9404.

2. U.S. Environmental Protection Agency. July 1993. Emission Factor Documentation for AP-42 Chapter 2.5 Sewage Sludge Incineration. p. 2.5-1.

3. U.S. Environmental Protection Agency. July 1993. Emission Factor Documentation for AP-42 Chapter 2.5 Sewage Sludge Incineration. p. 2.5-4.

4. U.S. Environmental Protection Agency. July 1993. Emission Factor Documentation for AP-42 Chapter 2.5 Sewage Sludge Incineration. p. 2.5-13 - 2.5-17.

5. ORTECH International. March 1990. MOE Toxic Chemical Emission Inventory for Ontario and Eastern North America. Prepared for Air Resources Branch, Ontario Ministry of the Environment. Draft Report No. P.89-50-5429/06. p. 173.

A.5 Hazardous Waste Incineration

Hazardous waste incineration occurs at on-site hazardous waste incinerators, commercial hazardous waste incinerators, mobile hazardous waste incinerators, and some boilers and industrial furnaces (BIFs). For the purposes of this 112(c)(6) inventory, only emissions estimates for dedicated hazardous waste incinerators are provided. The bulk of the data used to determine national estimates was obtained from EPA Office of Solid Waste (OSW) efforts on MACT regulatory programs for dedicated hazardous waste incinerators.[1] OSW was unable to provide information for development of a national estimate for BIFs; therefore, the estimates and supporting data shown here do not include BIFs.

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- Total PCBs

National Activity Level/Emission Estimates

Different activity levels will be used to estimate dioxin/furan and PCB national emissions. The activity data for dioxins/furans was derived from total quantities of incinerable hazardous waste generated. The PCB activity level was derived from data on the amount of PCB-contaminated waste generated and eventually burned for disposal.

In 1992, approximately 249 million metric tons of hazardous waste were generated.[2] Dempsey and Oppelt, 1993, estimate that of the total amount of hazardous waste generated, 1.3 million metric tons were burned in dedicated hazardous waste facilities.[3] Dedicated hazardous waste facilities are designed expressly to burn and destroy wastes, whereas BIFs are not. They simply burn hazardous wastes containing some heating value as a supplemental fuel. Waste destruction is achieved as a result of the high temperature combustion process.

National estimates for 2,3,7,8-TCDD and 2,3,7,8-TCDF were determined using literature data on emission factors and published data on the amount of hazardous waste destroyed in dedicated incinerators. The national estimate for 2,3,7,8-TCDD TEQ was obtained from EPA/OSW and represents a value determined as a part of the MACT regulatory development program. The TEQ estimate was based on facility data contained in OSW's incinerator database. Reported emissions were directly available for some sites. In cases where a direct value was not available for a facility, emissions were estimated by extrapolating data from unknown facilities to similar facilities based on flow rates, waste loads, waste characterization, etc. The direct emissions information in the database was used to the greatest extent possible to derive estimates for all other facilities. Individual facility emission rates, factors, and activity data were not provided by OSW for the purposes of this inventory document.

EPA's Office of Pollution Prevention and Toxic Substances, Operations Branch, used PCB disposal data to estimate that 3.4×10^{8} kilograms of PCBs were disposed of between 1990 and 1994.[4] Assuming equal quantities were disposed each year, the 1990 activity level is 6.8×10^{7} kilograms PCBs. Of this total, 37 percent were assumed to have been disposed of using incineration. All PCBs incinerated in 1990 were assumed to have been destroyed to a level of 99.9999 percent, which is the most stringent destruction level required by hazardous waste-burning regulations.[5]

Assumptions on Process and Control Levels

Oppelt, 1987 provides a table that shows the different types of hazardous waste incinerator control devices and their distribution among incinerators.[6] Approximately 35 percent of all hazardous waste incinerators control emissions with a Venturi scrubber. Other controls employed include packed tower scrubbers, liquid quenchers, ionizing wet scrubbers, wet scrubbers, wet ESPs, and other non-specified scrubbers. The emission factors used to develop national emissions are representative of an incinerator with a Venturi scrubber/packed column scrubber control configuration in place.

Emission Factors

Table A-8 lists the emission factors for each pollutant that were used to develop the national emissions estimate for hazardous waste incineration. Emission factors reported in the 1996 draft Dioxin/Furan L&E document for hazardous waste incinerators will be used to estimate national emissions of TCDD/TCDF for this inventory.[7] The factors were developed from testing performed at the EPA's Incineration Research Facility designed to evaluate PCB destruction and removal efficiency. The waste feed during testing was PCB-contaminated sediments. The test incinerator was equipped with a venturi scrubber followed by a packed column scrubber.

TABLE A-8. HAZARDOUS WASTE INCINERATION EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	8.42×10^{-11}	kg/Mg waste
2,3,7,8-TCDF	9.54×10^{-9}	kg/Mg waste
Total PCBs	1.0×10^{-3}	kg/Mg PCB incinerated

Hazardous waste incinerators are assumed to destroy PCBs and dioxins and furans to a level of 99.9999 percent. This analysis assumes that this destruction requirement is met by incineration facilities, which corresponds with a PCB emission factor of 0.001 g/kg total PCB incinerated.

Major/Area Source Assumptions

Based on data collected by EPA/OSW during MACT regulatory development work for these sources, a major/area split of 100/0 is assumed.

REFERENCES FOR HAZARDOUS WASTE INCINERATION

1. Memorandum from Rizeq, G., EER Corp. to F. Behan, U.S. Environmental Protection Agency, Office of Solid Waste. April 3, 1997. National Emissions Estimate for Hazardous Waste Incinerators.

2. Oppelt, E.T. 1987. Incineration of Hazardous Waste. A Critical Review. JAPCA. 37(5):558-586. p. 559.

3. Dempsey, C.R. and Oppelt, E.T. 1993. Incineration of Hazardous Waste: A Critical Review Update. Air and Waste. 43:25-73.

4. Memorandum from Baney, Tony, U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances to Laurel Driver, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. November 21, 1996. PCB production and emissions date.

5. Code of Federal Regulations. Part 40, Subpart H, Section 266.104. Government Printing Office. Washington, DC. July 1994.

6. Oppelt, E.T. 1987. Incineration of Hazardous Waste. A Critical Review. JAPCA. 37(5):558-586. p. 565.

7. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

A.6 Portland Cement

Pollutants Addressed

- 2,3,7,8-TCDD TEQ

National Activity Levels/Emission Estimates

The national emission estimates for the Portland cement source category were taken directly from estimates prepared by EPA to support the Portland Cement Manufacturing Industry NESHAP standards program. The program developed separate estimates for cement kilns depending on whether the kiln did or did not burn hazardous waste as a supplemental fuel. The details of the estimation process and the data used to develop national estimates can be found in References 1 and 2. A summary of the procedures and input data used is reported here.

Non-Hazardous Waste (NHW) Kilns

Emissions were only estimated on the basis of a dioxin/furan TEQ. Average TEQ emission factors were determined from actual test data for existing facilities of varying types, design, and control configurations. An average TEQ emission factor of 0.25 ng/dry standard cubic meter (dscm) of flow was determined and used for the national emissions calculation. The national kiln clinker production value used in the calculation was 67.6 million tons of clinker produced per year from NHW kilns. Additional key variables used in the estimation were 66,225 dscf of flow/ton dry feed material and 1.65 tons dry feed/ton of clinker produced. The values for these variables came from the Technical Background Document for the standard. The equation used to calculate the national emissions estimate was:[1]

$$\frac{\text{ng}}{\text{dscm}} \cdot \frac{\text{m}^3}{35.3\ \text{ft}^3} \cdot \frac{\text{g}}{10^9\ \text{ng}} \cdot \frac{\text{lb}}{454\ \text{g}} \cdot \frac{66{,}225\ \text{dscf}}{\text{ton dry feed}} \cdot$$

$$\frac{1.65\text{ton dry feed}}{\text{ton clinker}} \cdot \frac{\text{ton clinker}}{\text{yr}} = \frac{\text{lb TEQ}}{\text{yr}}$$

This equation is equivalent to an emission factor of 1.78×10^{-9} lb/ton.

Hazardous Waste (HW) Kilns

National emission estimates for 2,3,7,8-TCDD TEQ and mercury from Portland cement kilns burning hazardous wastes were determined from EPA/OSW and represent values estimated by them as a part of the MACT regulatory development program for this source category.[2] The TEQ estimate was based on facility data contained in OSW's cement kiln database. Reported emissions were directly available for some sites. In cases where a direct value was not available for a facility, emissions were estimated by extrapolating data from known facilities to similar facilities based on flow rates, waste loads, waste characterization, etc. The direct emissions information in the database was used to the greatest extent possible to derive estimates for all the other facilities. Individually facility emission rates, factors, and activity data were not provided by OSW for the purposes of this inventory document. 1990 national emissions from cement kilns burning hazardous waste are:

2,3,7,8-TCDD TEQ emissions = 0.95 pounds
mercury emissions = 3.5 tons

For comparison purposes, OSW-estimated 1996 TEQ and mercury emissions from this category are 0.13 pounds and 2.9 tons, respectively.[2]

Major/Area Source Assumptions

The number of Portland cement facilities in the U.S. that are major sources is not readily available. However, from recent MACT analysis, it is estimated that 100 percent of cement facilities combusting hazardous waste are major sources, and of the cement facilities not using hazardous waste fuels, 80 percent are major sources and 20 percent are area.

REFERENCES FOR PORTLAND CEMENT

1. Memorandum from E. Heath, Research Triangle Institute to J. Wood, U.S Environmental Protection Agency. March 18, 1996. "Dioxin/Furan Toxic Equivalent Emissions from Cement Kilns that do not Burn Hazardous Waste."

2. Memorandum from G. Rizeq, EER Corporation to F. Behan, U.S Environmental Protection Agency. April 7, 1997. "National Emissions Estimate for TEQ and Mercury."

A.7 Scrap Tire Incineration

Scrap tires are incinerated for energy recovery and disposal purposes. Tires are combusted at tire-to-energy facilities, cement kilns, tire manufacturing facilities, and as supplemental fuel in boilers, especially in the pulp and paper industry.

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- Total PCBs

National Activity Level/Emission Estimates

In 1990, 25.9 million of the 242 million tires discarded in the United States were converted to energy.[1] The EPA's Office of Solid Waste estimates that approximately 5.51×10^5 tons/yr of tires are incinerated each year.[2]

Assumptions on Process and Control Levels

The Modesto tire-to-energy facility uses a spray dryer and flue gas desulfurization followed by a fabric filter to control emissions.[3] The emission factors used to estimate national emissions were developed from emission testing at this facility.

Emission Factors

Table A-9 lists the emission factors for each pollutant that were used to develop the national emissions estimate for waste tire incineration. All emission factors were derived from source testing at the Modesto facility. We are assuming that other facilities burning waste tires have emissions similar to those occurring at the Modesto facility. The emission factors for total CDD/F and TCDD TEQ were obtained from the document "Estimating Exposure to Dioxin-like Compounds."[3] The ratios of CDD and CDF to total CDD/F, and TCDD and TCDF to TEQ were used to develop the CDD, CDF, TCDD, and TCDF emission factors.[4]

TABLE A-9. SCRAP TIRE INCINERATION EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	2.16×10^{-11}	lb/ton of tires
2,3,7,8-TCDF	5.42×10^{-11}	lb/ton of tires
2,3,7,8-TCDD TEQ	1.08×10^{-9}	lb/ton of tires
CDD	6.50×10^{-9}	lb/ton of tires
CDF	2.14×10^{-8}	lb/ton of tires
Total PCBs	3.78×10^{-6}	lb/ton of tires

Major/Area Source Assumptions

All scrap tire incineration facilities are assumed to be major sources. Most facilities that burn tires utilize other processes which generate toxic emissions.

REFERENCES FOR SCRAP TIRE INCINERATION

1. U.S. Environmental Protection Agency. October 1991. Markets for Scrap Tires. EPA/530-SW-90-074A. Office of Solid Waste and Emergency Response. p. 8.

2. U.S. Environmental Protection Agency. September 1991. Summary and Markets for Scrap Tires. Office of Solid Waste and Emergency Response. EPA/530 - SW-90-074B.

3. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. pp. 3-70 - 3-71.

4. Radian Corporation. April 1988. Modesto Energy Company Waste Tire to Energy Facility, Westley, CA - Final Emission Test Report. Report No. 243-047-20.

A.8 Electric Utility Coal Combustion

Pollutants Addressed

- EOM
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ

National Activity Levels/Emission Estimates

The national activity level for electric utility coal combustion by coal type for the base year 1990 is:

- 772,552,000 tons of bituminous coal burned[1]
- 1,031,000 tons of anthracite coal burned[1]

The national activity level is reported by State in the referenced Energy Information Administration (EIA) State energy consumption database. The EOM emission factor data were not available for boilers burning anthracite; however, anthracite coal use accounts for less than 1 percent of the coal burned in the utility sector.[2] The activity level for bituminous coal includes lignite coal as well. Based on 1989 coal production estimates, approximately 9 percent of the total bituminous coal burned is actually lignite coal.[2] This percentage was used to develop the weighted emission-factor for EOM provided below.

The emission estimate for EOM was derived as described here. The national estimates for 2,3,7,8-TCDD, 2,3,7,8-TCDF, and 2,3,7,8-TCDD TEQ came directly from EPA's in progress work to prepare a Clean Air Act mandated Report to Congress on toxics from the utility industry.[3]

Assumptions on Process and Control Levels

There are four basic types of coal-fired utility boilers for which EOM emission factors are available: pulverized dry bottom, pulverized wet bottom, cyclone, and stoker. Of these, the most prevalent boiler type is pulverized dry bottom, which represents approximately 76 percent of the total coal fuel use.[4] Pulverized wet bottom designs account for about 11 percent, while cyclone boilers make up approximately 12 percent of the coal use.[4] Stokers, which have been phased out of the utility sector due to their inefficiency, account for only 1 percent of the utility sector coal use.[4] These percentages were used to develop the weighted EOM emission factor provided below.

The emissions test data, from which the EOM emission factor presented below is developed, is based on testing of 26 coal-fired boilers. Of these 26, 17 had ESP control devices and 4 had multiclone control devices. The remainder had a mix of mechanical precipitators, wet scrubbers, and baghouses. Therefore, all the test sites had some level of pollution control devices installed and the EOM emission factor was developed from flue gas samples taken downstream of the control devices.

Emission Factors

The EOM emission factors that were used to develop the national EOM emissions estimate for electric utility coal combustion is 0.10 lb EOM/short ton of coal burned. The emission factor is based on test studies conducted by EPA in it Emissions Assessment of Conventional Stationary Combustion Systems,[5] and the application of weighting factors for design type and coal type as described above. The original emission factor from those test studies were in units of ng per Joule of thermal input. For this inventory, a thermal conversion factor of 20.935 x 10^6 Btu per short ton of coal was to calculate the EOM emission factor listed above.[6]

The EPA is developing a Clean Air Act Amendments (CAAA)-mandated Report to Congress on toxics from utility sources, and emissions data based on boiler tests conducted over the past several years were obtained. Table A-10 contains 2,3,7,8-TCDD/ 2,3,7,8-TCDF emission factors for coal-fired units.[7] It is important to note that these data are preliminary and have not been finalized yet. In addition, the factors are for a composite of various furnace configurations and control devices.

TABLE A-10. ELECTRIC UTILITY COAL COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	3.62×10^{-11}	lb/on coal burned
2,3,7,8-TCDF	8.79×10^{-11}	lb/ton coal burned
2,3,7,8-TCDD TEQ	3.88×10^{-10}	lb/ton coal burned
EOM	0.10	lb/ton coal burned

Major/Area Source Assumptions

The category of electric utility coal combustion is assumed to be strictly a major source, with all coal-fired utility boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the consideration of other HAP emissions from these types of boilers, specifically hydrochloric acid (HCl) and hydrofluoric acid (HF). Documented emission factors for HCl and HF in the EPA's PISCES Database,[8] a compilation of emissions test data on electric utility power plants, indicates that most coal-fired boilers in this sector would be major sources. Further evaluation of the emission factor data in this database will be necessary to confirm this assumption. Also, based on the total estimated number of coal-fired boilers (1,076) and a preliminary estimate of national EOM emissions (38,628 tons/year), the average EOM emissions per boiler would be 35 tons/year, which would classify these boilers as major sources based on EOM emissions alone.

REFERENCES FOR ELECTRIC UTILITY COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. U.S. Environmental Protection Agency. 1993. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Section 1-1. Bituminous Coal Combustion, AP-42 Sections Under Review. p. 2-2.

3. Memorandum from J.D. Cole, Research Triangle Institute to W. Maxwell, U.S. Environmental Protection Agency. January 19, 1995. "HAP Emission Factors and National Emissions for Utility Boilers."

4. Radian Corporation. 1989. Estimating Air Toxic Emissions from Coal and Oil Combustion Sources. EPA-450/2-89-001. Research Triangle Park, North Carolina. p. 3-76.

5. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory. Research Triangle Park, North Carolina. pp. 36 - 37.

6. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 477.

7. Memorandum from J.D. Cole, Research Triangle Institute, to William Maxwell, U.S. Environmental Protection Agency. HAP Emission Factors. January 19, 1995.

8. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, Texas. pp. 2-3 - 2-10.

A.9 Electric Utility Residual Fuel Oil Combustion

Pollutants Addressed

- EOM
- PCB
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ

National Activity Levels/Emission Estimates

The national activity level for electric utility residual fuel oil combustion for the base year 1990 is 181,232,000 barrels residual fuel oil burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database. Emission factors will be used to estimate emissions associated with the national and State level activity data. The national activity level for PCBs is 304,470 pounds of PCBs burned per year by the electric utility industry associated with PCB contaminated residual oil combustion. For the purpose of this inventory, it is assumed that 10 percent of the residual oil burned by utilities is contaminated with PCBs. For conservative estimation purposes, the concentration of PCBs in the residual oil is assumed to be 50 ppm, since PCBs at this or lower concentrations can be burned for energy recovery purposes (40 CFR 279). The corresponding national activity level for PCBs is 304,470 pounds of PCBs burned.

The emission estimates for EOM and PCBs were derived as described here. The national estimates for 2,3,7,8-TCDD, 2,3,7,8-TCDF, and 2,3,7,8-TCDD TEQ came directly from EPA's in progress work to prepare a Clean Air Act mandated Report to Congress on toxics from the utility industry (see Reference 6).

Assumptions on Process and Control Levels

The EPA study[2] on which the EOM emission factor presented below is based included emissions tests at four tangentially-fired and eight wall-fired boilers; emission factors for EOM were the same for both boiler designs.[3] Five of the boilers contained no emission control devices, three had ESPs, three used off-stoichiometric firing and one contained a cyclone separator. Therefore, the EOM emission factor presented below represents a mix of both controlled and uncontrolled boilers. The PCB emission factor of 1 lb/10^6 PCB burned is based on an assumed destruction efficiency of 99.9999 percent (i.e., 1 part by weight in a million).

Emission Factors

Table A-11 lists the emission factors for each pollutant that were used to develop the national emissions estimate for electric utility residual fuel combustion. The EOM emission factor represents an average of the 12 boilers tested in the EPA study referenced above. The emission factor from the EPA study (0.4 ng/Joule of thermal input) was converted to the units shown in Table A-11 using the thermal conversion factor of 6.287 x 10^6 Btu per barrel of residual oil.[4] An emission factor for PCBs was derived from the assumption that all boilers attain 99.9999 percent destruction efficiency for toxic organics, as required in the most stringent BIF hazardous waste destruction rules.[5]

The EPA is developing a CAAA-mandated Report to Congress on toxics from utility sources, and emissions data based on boiler tests conducted over the past several years were obtained. Table A-11 contains draft 2,3,7,8-TCDD and 2,3,7,8-TCDF emission factors for oil-fired units.[6] It is important to note that these data are preliminary and have not been finalized yet. In addition, the factors are for a composite of various furnace configurations and control devices.

TABLE A-11. ELECTRIC UTILITY RESIDUAL FUEL COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor	Units
EOM	5.86	lb/10^3 barrels of residual fuel oil consumed
PCB	1	lb/10^6 lb PCB burned
2,3,7,8-TCDD	4.0×10^{-11}	lb/barrels oil burned
2,3,7,8-TCDF	2.9×10^{-11}	lb/barrels oil burned
2,3,7,8-TCDD TEQ	1.1×10^{-10}	lb/barrels oil burned

Major/Area Source Assumptions

The category of electric utility residual fuel combustion is assumed to be primarily a major source category. This assumption is based on the observation, drawn from DOE utility reporting data for 1990,[7] that most of the boilers in this sector are rated at a thermal input capacity of greater than 500 MMBtu/hour and that there is typically more than one boiler located at a power plant facility. Considering the emission factors for benzene, nickel, and POM, which are documented[8] for these types of boilers, and the observation just stated, an apportionment of 90 percent major sources and 10 percent area sources were made for this category. The 10 percent area sources represents a small fraction of boilers in this sector that have thermal input capacities less than 500 MMBtu/hour and which are not co-located at power plant facilities with other boilers.

REFERENCES FOR ELECTRIC UTILITY RESIDUAL FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Shih, C.C. 1987. Emissions Assessment of Conventional Stationary Combustion Systems, Volume III: External Combustion Sources for Electricity Generation. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 160.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. Industrial Environmental Research Laboratory. Research Triangle Park, North Carolina. p. 38.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 479.

5. Code of Federal Regulations. Part 40, Subpart H, Section 266.104. Government Printing Office. Washington, DC. July 1994.

6. Memorandum from J.D. Cole, Research Triangle Institute, to William Maxwell, U.S. Environmental Protection Agency. January 19, 1995. "HAP Emission Factors".

7. U.S. Department of Energy. 1990. Form EIA-767 Reporting Data for 1990. Information Contained on File Labeled "Int90ut2.dat") on the EPA CHIEF Bulletin Board. Research Triangle Park, North Carolina.

8. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, Texas. p. 2-11.

A.10 Electric Utility Natural Gas Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for industrial natural gas-fired boilers for the base year 1990 is 2,787 x 10^9 cubic feet natural gas burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database. Emissions will be estimated using the State level activity data and the EOM emission factor provided below.

Assumptions on Process and Control Levels

The EOM emission factor presented below is based on test results from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume III: External Combustion Sources for Electricity Generation.[2] Emissions testing was conducted on eight natural gas-fired utility boilers as part of that study. Three of the boilers were tangentially-fired, while the remaining five were wall-fired designs. There were no pollution control devices on six of the boilers tested; only two of the wall-fired boilers used overfire air for NO_X control.

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for natural gas-fired utility boilers is 720.42 lb EOM/10^9 cubic feet of natural gas consumed. This EOM emission factor represents an average of the test results[3] for the eight boilers in the EPA study referenced above. The emission factor from the EPA study (0.3 ng/Joule of thermal input) was converted to the emission factor shown above using the thermal conversion factor of 1.03 x 10^3 Btu per cubic foot of natural gas.[4]

Major/Area Source Assumptions

The category of electric utility natural gas-fired boilers is assumed to be primarily a major source category. This assumption is based on information contained in the DOE utility reporting database for 1990[5] and emission factors for HCl, nickel, and phosphorous contained in the PISCES Database.[6] The DOE utility reporting database for 1990 indicates that most of the boilers in this sector have thermal input capacities greater than 500 MMBtu/hour. Using the emission factors from PISCES for HCl, nickel, and phosphorous, and a 500 MMBtu/hour thermal input capacity, most of these boilers would be classified as major sources considering their co-location with at least one other similar rated boiler at a power plant facility. For the purposes of this inventory, 90 percent of the boilers in this category will be classified as major sources, while 10 percent will be classified as area sources to reflect the small fraction of these boilers that have thermal input ratings under 500 MMBtu/hour and/or which are not co-located with another boiler at a power plant facility.

REFERENCES FOR ELECTRIC UTILITY NATURAL GAS COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Shih, C.C. 1987. Emissions Assessment of Conventional Stationary Combustion Systems, Volume III: External Combustion Sources for Electricity Generation. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 160.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 38.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 471.

5. U.S. Department of Energy. 1990. Form EIA-767 Reporting Data for 1990. Information Contained on File Labeled "Int90ut2.dat") on the EPA CHIEF Bulletin Board. Research Triangle Park, North Carolina.

6. Radian Corporation. 1992. Evaluation of Emissions Information in the PISCES Database. Final Report. Prepared for Utility Air Regulatory Group. Austin, Texas. p. 2-13.

A.11 Industrial Coal Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for industrial coal combustion by coal type for the base year 1990 is:

- 114,815,000 tons of bituminous and lignite coal burned[1]
- 390,000 tons of anthracite coal burned[1]

The national activity level is reported by State in the referenced EIA State energy consumption database. The EOM emission factor data were not available for industrial boilers burning anthracite coal and no emissions will be estimated for anthracite coal combustion; however, anthracite coal accounts for less than 1 percent of the coal burned in this sector.

Assumptions on Process and Control Levels

There are three types of industrial boilers for which an EOM emission factor is available: pulverized dry bottom, pulverized wet bottom, and stokers. Total coal use in the industrial sector among these boiler types is approximately 45 percent pulverized dry bottom, 45 percent stoker, and 10 percent pulverized wet bottom.[2] These percentages were used to derive the weighted EOM emission factor presented below. Of the eight test sites from which the EOM emissions data were collected, three contained ESP control devices and the remaining five had multiclone control devices. The EOM emission factor below, therefore, represents a controlled emission factor based on emission samples taken in the flue gas downstream of the control device.[3]

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for industrial coal-fired boilers is 0.042 lb EOM/short ton of coal consumed. This emission factor is based on test studies conducted by EPA in it's Emissions Assessment of Conventional Stationary Combustion Systems,[4] and the application of the weighting factors for boiler design type described above. The emission factor from the EPA studies (0.8 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 22.444×10^6 Btu per short ton of bituminous/lignite coal.[5]

Major/Area Source Assumptions

The category of industrial coal-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of coal-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

REFERENCES FOR INDUSTRIAL COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Radian Corporation. 1989. Estimating Air Toxic Emissions from Coal and Oil Combustion Sources. EPA-450/2-89-001. Research Triangle Park, North Carolina. p. 3-76.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 50 - 51.

4. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency,

Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 50 - 51.

5. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 475.

A.12 Industrial Distillate Fuel Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for industrial distillate fuel-fired boilers for the base year 1990 is 39,000,000 barrels distillate fuel burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database. The activity level labeled as "Industrial" in the EIA consumption database includes distillate fuel consumed in stationary internal combustion turbines and engines, and in non-road vehicles and equipment, as well as external combustion boilers. In order to avoid double-counting this activity level, 164 million barrels were subtracted from the total reported consumption (203 million barrels), to account for distillate fuel use associated with these other source categories. The Fuel Oil and Kerosene Sales 1990 annual report,[2] also compiled by EIA, was used to calculate the amount of diesel associated with these other categories, since they are not reported separately in the EIA consumption database. Emission factors will be used to estimate emissions associated with the national and State level activity data.

Assumptions on Process and Control Levels

The EOM emission factor presented below is based on emissions test data from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources.[3] Emissions testing was conducted on three distillate fuel-fired watertube type boilers. All of the boilers tested contained no pollution control devices.

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for industrial distillate fuel-fired boilers is 20.37 lb EOM/10^3 barrels of distillate fuel oil consumed. This is an uncontrolled emission factor for EOM, based on an average of the test results[4] for the three boilers that were part of the EPA study referenced above. The emission factor developed as part of the EPA study (1.5 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 5.825 x 10^6 Btu per barrel of distillate fuel oil.[5]

Major/Area Source Assumptions

The category of industrial distillate fuel-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of distillate fuel-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

REFERENCES FOR INDUSTRIAL DISTILLATE FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Energy Information Administration. 1991. Fuel Oil and Kerosene Sales 1990. Office of Oil and Gas, U.S. Department of Energy, Washington, DC. p. 9.

3. Surprenant, N.F., et al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources. GCA-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 81.

4. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 50.

5. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 478.

A.13 Industrial Residual Fuel Oil Combustion

Pollutants Addressed

- EOM
- PCB

National Activity Levels/Emission Estimates

The national activity level for industrial residual fuel-fired boilers for the base year 1990 is 65,931,000 barrels residual fuel burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database. Emission factors will be used to estimate emissions associated with the national and State level activity data. The national activity level for PCBs is 110,764 pounds of PCBs burned. For the purpose of this inventory, it is assumed that 10 percent of the residual oil burned by industrial boilers is contaminated with PCBs. For conservative estimation purposes, the concentration of PCBs in the residual oil is assumed to be 50 ppm, since PCBs at this or lower concentrations can be burned for energy recovery purposes (40 CFR 279).

Assumptions on Process and Control Levels

The EPA test data on which the EOM emission factor is based included five residual fuel-fired boilers, three of which were watertube designs and two that were drumless serpentine designs. Only one of the watertube boilers had a multiclone pollution control device. All other boilers in the test data had no controls.[2]

Emission Factors

Table A-12 lists the emission factors for each pollutant that were used to develop the national emissions estimate for industrial residual fuel-fired boilers. The EOM emission factor represents an average of the test results[3] for the five boilers tested in the EPA study referenced above. The EOM emission factor developed as part of the EPA study (0.2 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 6.287×10^6 Btu per barrel of residual fuel oil.[4] An emission factor for PCBs was derived from the assumption that all boilers and industrial furnaces attain 99.9999 percent destruction efficiency for PCBs.

TABLE A-12. INDUSTRIAL RESIDUAL FUEL COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor	Units
EOM	2.93	lb/10^3 barrels of residual fuel oil consumed
PCB	1	lb/10^6 lb PCB burned

Major/Area Source Assumptions

The category of industrial residual fuel-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of residual fuel-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

REFERENCES FOR INDUSTRIAL RESIDUAL FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources. GCR-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 81.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 50.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 479.

A.14 Industrial Natural Gas Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for industrial natural gas-fired boilers for the base year 1990 is 7,732 x 10^9 cubic feet natural gas burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database. From the total reported consumption for the industrial sector (8204 x 10^9 cubic feet), 472 x 10^9 cubic feet were subtracted to account for natural gas use associated with stationary internal combustion turbines (see Section A.33 for a discussion on the derivation of natural gas consumption for that category).

Assumptions on Process and Control Levels

The EOM emission factor presented below is based on test results from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources.[2] Emissions testing was conducted on 10 natural gas-fired boilers as part of that study. Seven of the boilers were watertube designs, two were firetubes, and one was a packaged scotch type boiler. There were no pollution control devices on any of the boilers tested.

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for industrial natural gas-fired boilers is 240.14 lb EOM/10^9 cubic feet of natural gas consumed. This EOM emission factor represents uncontrolled conditions and is an average of the test results[3] for the 10 boilers in the EPA study referenced above. The emission factor developed as part of the EPA study (0.1 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 1.03×10^3 Btu per cubic foot of natural gas.[4]

<u>Major/Area Source Assumptions</u>

The category of industrial natural gas-fired boilers is assumed to be a 70 percent major/30 percent area source, with 70 percent of natural gas-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This assumption is based on the fact that many of these boilers are co-located at manufacturing facilities that are major sources because of their manufacturing process.

REFERENCES FOR INDUSTRIAL NATURAL GAS COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 -344.

2. Surprenant, N.F. 1987. Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 80.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 50.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 471.

A.15 Industrial Wood Combustion

Pollutants Addressed

- EOM
- 2,3,7,8-TCDD TEQ

National Activity Levels/Emission Estimates

The national activity level for industrial wood combustion for the base year 1990 is 90.6 x 10^6 short tons oven dried wood burned.[1] The national activity level is reported by region (South, West, Northeast, Midwest) in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

Industrial wood-fired boilers are generally located at facilities which produce wood and bark waste products, including pulp and paper mills, lumber mills, furniture plants, and plywood mills. There are various boiler firing configurations used in industrial wood combustion. Three of the most common wood-fired boiler types in use are the Dutch oven, the fuel cell and the spreader stoker. The four most common PM emission control technologies in use are mechanical collectors (multicyclone), wet scrubbers, ESPs and fabric filters.[2] The dioxin/furan emission factors used in this inventory represent the average of the two following process, control, and fuel type scenarios for which test data was available:

- A 3-cell Dutch oven firing a mixture of bark, salt laden hogged wood, sawdust, and planer shavings controlled by a multicyclone and a baghouse; and
- A quad-cell boiler firing coarse wood waste and sawdust controlled by a multicyclone.

The EOM emission factor is based on an average of the EPA emissions tests done for five stoker type boilers. Three of these boilers had no pollution control devices. The other two had scrubber type controls.[3]

Emission Factors

Table A-13 lists the emission factors for each pollutant that were used to develop the national emissions estimate for industrial wood-fired boilers.

TABLE A-13. INDUSTRIAL WOOD COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor	Units
EOM	2.16	lb/short ton of dry wood burned
2,3,7,8-TCDD TEQ	2.48×10^{-9}	lb/short ton of dry wood burned
2,3,7,8-TCDD	7.34×10^{-11}	lb/short ton of dry wood burned
2,3,7,8-TCDF	1.05×10^{-10}	lb/short ton of dry wood burned

The dioxin/furan emission factors were derived from U.S. facility test reports.[4] The TEQ factor was obtained from recent test data results supplied by the pulp and paper industry.[5] The process, fuel and control configurations of both units tested are described above. The EOM emission factor is based on the average of the tests[6] conducted on emission samples from the flue gas for the five wood-fired stoker boilers described above. The emission factor from these tests (54 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 17.2×10^6 Btu per oven-dried short ton of wood.[7]

Major/Area Source Assumptions

The category of industrial wood-fired boilers is assumed to be a 80 percent major/20 percent area source, with 80 percent of wood-fired industrial boilers emitting more than

10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. The higher percentage of major sources is due to the co-location of many of these boilers at pulp and paper facilities which are likely to be major sources.

REFERENCES FOR INDUSTRIAL WOOD COMBUSTION

1. Energy Information Administration. 1991. Estimate of U.S. Biofuels Consumption 1990. Washington, DC. U.S. Department of Energy, Office of Coal, Nuclear, Electric, and Alternative Fuels. DOE/EIA-0548(90). p. 9.

2. U.S. Environmental Protection Agency. October 1992. Emission Factor Documentation for AP-42, Section 1.6 - Wood Waste Combustion in Boilers. Draft Report. Technical Support Division, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

3. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume V: Industrial Combustion Sources. GCR-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 82.

4. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, 5th Edition, AP-42, Volume I: Stationary Point and Area Sources, Section 16., Wood Waste Combustion Boilers. Research Triangle Park, North Carolina. 1995.

5. Someshwar, A.V. Summary of Mill Test Reports on Wood Residue Combustion, Black Liquor Combustion, and Kraft Mill Sludge Burning. NCASI Files, Confidential. Gainesville, Florida: National Council of the Paper Industry for Air and Stream Improvement, Inc., 1995.

6. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 51.

7. Energy Information Administration. 1991. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 28.

A.16 Commercial/Institutional Coal Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for commercial/institutional coal combustion by coal type for the base year 1990 is:

- 3,575,000 tons bituminous and lignite coal burned[1]
- 493,000 tons anthracite coal burned[1]

The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The EOM emission factor presented below is based on emission tests conducted by the EPA as part of it's Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources.[2] As part of this study, two bituminous pulverized dry bottom boilers, three bituminous stokers, and three anthracite stokers were selected for testing. One of the bituminous pulverized dry bottom boilers had a multiclone/scrubber pollution control device, and two of the bituminous stokers had mechanical precipitators. The remaining boilers in the test had no control devices. In order to calculate a single weighted emission factor as presented below, the following percentages of coal use by boiler design in the commercial sector were used: 85 percent stoker and 15 percent pulverized dry bottom.[3] In addition, the stoker fraction was weighted by the relative consumption of bituminous and anthracite coal; approximately 88 percent bituminous and 12 percent anthracite.

Emission Factors

The emission factors for EOM that were used to develop the national emissions estimate for commercial/institutional coal combustion is 1.35 lb EOM/short ton of coal consumed. This EOM emission factor[4] is a composite emission factor that represents all the boiler designs and fuel types described above. The emission factor from the EPA's test study (25.2 ng/Joule of thermal input) was converted to the emission factor presented above using the thermal conversion factor of 22.98 x 10^6 Btu per short ton of coal consumed.[5]

Major/Area Source Assumptions

The category of commercial/institutional coal combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all coal-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 -344.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCR-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 51 - 52.

3. Radian Corporation. 1989. Estimating Air Toxic Emissions from Coal and Oil Combustion Sources. EPA-450/2-89-001. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. p. 3-76.

4. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 46 - 47.

5. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 465 and 473.

A.17 Commercial/Institutional Distillate Fuel Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for commercial/institutional distillate fuel combustion by coal type for the base year 1990 is 83,605,000 barrels distillate fuel burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The EOM emission factor presented below was developed from emissions test data collected by the EPA as part of it's Emissions Assessment of Conventional Stationary Combustion Systems.[2] Emissions testing was conducted at three distillate fuel-fired boilers in that study. Two of these boilers were of the watertube design, while the third was a packaged cast iron type. There were no control devices on any of the three boilers that were tested.

Emission Factors

The emission factors for EOM that were used to develop the national emissions estimate for commercial/institutional distillate fuel combustion is 23.09 lb EOM/1000 barrels of distillate fuel consumed. This EOM emission factor represents an average factor for the three boilers that are described above and represents uncontrolled conditions. The emission factor from the EPA's study (1.7 ng/Joule of thermal input)[3] was converted to the emission factor presented above by using the thermal conversion factor of 5.825×10^6 Btu per barrel of distillate fuel.[4]

Major/Area Source Assumptions

The category of commercial/institutional distillate fuel combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all distillate-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL DISTILLATE FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 -344.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCR-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 54.

3. Shih, C.C. and A.M. Takata, et. al. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 46 - 47.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 478.

A.18 Commercial/Institutional Residual Fuel Oil Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for commercial/institutional residual fuel combustion for the base year 1990 is 59,551,000 barrels residual fuel burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The EOM emission factor presented below was developed from emissions test data collected by EPA as part of it's Emissions Assessment of Conventional Stationary Combustion Sources.[2] Emissions testing was conducted at five residual fuel-fired boilers in that study. Four of these boilers were of the watertube design, while the fifth was a packaged firetube design. There were no control devices present on any of the boilers that were tested.

Emission Factors

The emission factors for EOM that were used to develop the national emissions estimate for commercial/institutional residual fuel combustion is 11.73 lb EOM/1000 barrels of residual fuel consumed. This EOM emission factor represents an average factor for the five boilers tested, as described above, and represents uncontrolled conditions. The emission factor from the EPA's study (0.8 ng/Joule of thermal input)[3] was converted to the emission factor presented above by using the thermal conversion factor of 6.287 x 10^6 Btu per barrel of residual fuel.[4]

Major/Area Source Assumptions

The category of commercial/institutional residual fuel combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all residual oil-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL RESIDUAL FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 -344.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCR-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 54.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 46 - 47.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 479.

A.19 Commercial/Institutional Natural Gas Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for commercial/institutional natural gas combustion for the base year 1990 is 2,677 x 10^9 cubic feet natural gas burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The EOM emission factor presented below was developed from emissions test data collected by the EPA as part of it's Emissions Assessment of Conventional Stationary Combustion Sources.[2] Emissions testing was conducted at five natural gas-fired boilers in that study. All five of the boilers were of the packaged watertube design. There were no control devices present on any of the boilers.

Emission Factors

The EOM emission factor that was used to develop the national emissions estimate for commercial/institutional natural gas combustion is 1440.85 lb EOM/10^9 cubic feet of natural gas consumed. This EOM emission factor represents an average factor for the five boilers tested, as described above, and represents uncontrolled conditions. The emission factor from the EPA's study (0.6 ng/Joule of thermal input)[3] was converted to the emission factor presented above using the thermal conversion factor of 1.03 x 10^3 Btu per cubic foot of natural gas.[4]

Major/Area Source Assumptions

The category of commercial/institutional natural gas combustion is assumed to be a 20 percent major/80 percent area source, with 20 percent of all coal-fired commercial/institutional facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL NATURAL GAS COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39-344.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCA-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 53.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 46 - 47.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 471.

A.20 Commercial/Institutional Wood Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for commercial/institutional wood combustion for the base year 1990 is 1.7 x 10^6 short tons oven dried wood burned.[1] The national activity level is based on a 1986 Nonresidential Buildings Energy Consumption Survey conducted by EIA and reported in the referenced EIA State energy consumption database. Commercial sector wood consumption is not normally reported in that database because there are no accurate data sources to provide reliable estimates.

Assumptions on Process and Control Levels

Wood-fired boilers make up only 2 percent of the overall fuel consumption in the commercial/institutional sector; petroleum (distillate and residual fuel oil) and natural gas account for approximately 96 percent of the fuel use in this sector for external combustion.[2]

The EOM emission factor presented below is based on test results from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources.[2] Emissions testing was conducted on one underfeed, wood stoker type boiler as part of that study. There were no pollution control devices on the boiler tested.

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for commercial/institutional wood-fired boilers is 2.29 lb EOM/short ton of dry wood burned. This EOM emission factor represents uncontrolled conditions. The emission factor from the EPA's study (57 ng/Joule of thermal input)[3] was converted to the emission factor presented above using the thermal conversion factor of 17.2 x 10^6 Btu per oven-dried short ton of wood.[4]

Major/Area Source Assumptions

The category of commercial/institutional wood-fired boilers is assumed to be 20 percent major/80 percent area sources, with 20 percent of wood-fired industrial boilers emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR COMMERCIAL/INSTITUTIONAL WOOD COMBUSTION

1. Energy Information Administration. 1991. Estimate of U.S. Biofuels Consumption 1990. DOE/EIA-0548(90). U.S. Department of Energy, Office of Coal, Nuclear, Electric, and Alternative Fuels, Washington, DC. p. 6.

2. Surprenant, N.F., et. al. 1980. Emissions Assessment of Conventional Stationary Combustion Systems, Volume IV: Commercial/Institutional Combustion Sources. GCA-TR-79-62-G. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 2 and 55.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 47.

4. Energy Information Administration. 1991. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 28.

A.21 Residential Coal Combustion

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Levels/Emission Estimates

The national activity level for residential coal combustion by coal type for the base year 1990 is:

- 1,929,000 tons bituminous and lignite coal burned[1]
- 732,000 tons anthracite coal burned[1]

The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

Emissions from residential coal combustion are assumed to be uncontrolled.

Emission Factors

Table A-14 lists the emission factors for each pollutant that were used to develop the national emissions estimate for residential coal combustion.

TABLE A-14. RESIDENTIAL COAL COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor (lb/ton Coal Burned)
Anthracite Coal	
2,3,7,8-TCDD	3.20×10^{-9}
2,3,7,8-TCDF	8.39×10^{-8}
2,3,7,8-TCDD TEQ	1.2×10^{-7}
CDD	5.73×10^{-7}
CDF	1.83×10^{-6}
Bituminous Coal	
2,3,7,8-TCDD	4.79×10^{-9}
2,3,7,8-TCDF	1.26×10^{-7}
2,3,7,8-TCDD TEQ	1.97×10^{-7}
CDD	8.67×10^{-7}
CDF	2.82×10^{-6}

The dioxin/furan emission factors are based on dioxin/furan concentrations in soot samples collected from 7 coal furnaces and AP-42 particulate emission factors.[2] 2,3,7,8-TCDD/TCDF isomer specific emission factors and homologue totals were used in calculating 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1986 scheme.[3]

Major/Area Source Assumptions

The category of residential coal combustion is assumed to be strictly an area source, with no single coal-fired furnace emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR RESIDENTIAL COAL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC.

2. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

3. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and -Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.22 Residential Distillate Fuel Combustion

Pollutants Addressed

- EOM
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Levels/Emission Estimates

The national activity level for residential distillate fuel combustion for the base year 1990 is 143,755,000 barrels distillate fuel burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

Emissions from these furnaces were all uncontrolled. The EOM emission factor presented below is based on emissions test data from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume I: Gas- and Oil-fired Residential Heating Sources.[2] Emissions testing was conducted for seven, conventional high pressure designed residential furnaces. Five of these were of the forced air variety, and the other two were forced hot water designs.

Emission Factors

Table A-15 lists the emission factors for each pollutant that were used to develop the national emissions estimate for residential distillate fuel combustion.

TABLE A-15. RESIDENTIAL DISTILLATE FUEL COMBUSTION EMISSION FACTORS

Pollutant	Emission Factor	Units
EOM	20.37	lb/10^3 barrels
2,3,7,8-TCDD	1.96×10^{-8}	lb/10^3 barrels
2,3,7,8-TCDF	1.86×10^{-8}	lb/10^3 barrels
2,3,7,8-TCDD TEQ	5.26×10^{-8}	lb/10^3 barrels
CDD	1.47×10^{-7}	lb/10^3 barrels
CDF	4.91×10^{-7}	lb/10^3 barrels

The EOM emission factor represents an average factor for the five furnaces that were tested in the EPA's study referenced above. The emission factor from the EPA study (1.5 ng/Joule of thermal input)[3] was converted to the EOM emission factor presented above using the thermal conversion factor of 5.825×10^6 Btu per barrel of distillate fuel.[4]

The dioxin/furan emission factors are based on dioxin/furan concentrations in soot samples from 21 distillate fuel-fired furnaces used in central heating and AP-42 particulate emission factors.[5] 2,3,7,8-TCDD/TCDF isomer specific emission factors and homologue totals were used in calculating 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1986 scheme.[6]

<u>Major/Area Source Assumptions</u>

The category of residential distillate fuel combustion is assumed to be strictly an area source, with no single distillate fuel-fired furnace emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR RESIDENTIAL DISTILLATE FUEL COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 -344.

2. Surprenant, N.F., et. al. 1979. Emissions Assessment of Conventional Stationary Combustion Systems, Volume I: Gas- and Oil-fired Residential Heating Sources. EPA-600/7-79-029b. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 37.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory. Research Triangle Park, North Carolina. p. 31.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 478.

5. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

6. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and -Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.23 Residential Natural Gas Combustion

Pollutants Addressed

- EOM

National Activity Levels/Emission Estimates

The national activity level for residential natural gas combustion for the base year 1990 is 4,313 x 10^9 cubic feet natural gas burned.[1] The national activity level is reported by State in the referenced EIA State energy consumption database.

Assumptions on Process and Control Levels

The EOM emission factor presented below is based on emissions test data from the EPA's Emissions Assessment of Conventional Stationary Combustion Systems, Volume I: Gas- and Oil-fired Residential Heating Sources.[2] Emissions testing was conducted for six natural gas-fired, conventional forced air heating furnaces. There were no emission control devices on these furnaces and none are assumed to be present for this inventory.

Emission Factors

The emission factor for EOM that was used to develop the national emissions estimate for residential natural gas combustion is 1921.13 lb EOM/10^9 cubic feet of natural gas consumed. This emission factor represents an average of the test results for the six furnaces that were part of the EPA study referenced above. The emission factor from the EPA study (0.8 ng/Joule of thermal input)[3] was converted to the emission factor presented above using the thermal conversion factor of 1.03 x 10^3 Btu per cubic foot of natural gas.[4]

<u>Major/Area Source Assumptions</u>

The category of residential natural gas combustion is assumed to be strictly an area source, with no single natural gas-fired residential furnace emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR RESIDENTIAL NATURAL GAS COMBUSTION

1. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 39 - 344.

2. Surprenant, N.F., et. al. 1979. Emissions Assessment of Conventional Stationary Combustion Systems, Volume I: Gas- and Oil-fired Residential Heating Sources. EPA-600/7-79-029b. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 37.

3. Shih, C.C. and A.M. Takata. 1981. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory. Research Triangle Park, North Carolina. p. 31.

4. Energy Information Administration. 1992. State Energy Data Report. Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. p. 471.

A.24 Residential Wood Combustion

Pollutants Addressed

- EOM
- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Level

29.1 million cords (33.8 million tons) of wood were combusted in residential wood combustors in 1990.[1,2] The nationwide percentage of wood consumption is 28 percent for fireplaces and 72 percent for woodstoves.[2] Of the 72 percent combusted in woodstoves, no more than five percent is combusted in catalytic and noncatalytic stoves.[3] For calculational purposes, it is assumed the remaining 95 percent (of the 72 percent) is combusted in conventional woodstoves.

EOM Emissions Estimate

The EOM emission factors for woodstoves were developed from emissions data resulting from 12 tests on a conventional woodstove and two tests on a catalytic woodstove.[4] A factor was developed for conventional woodstoves from the conventional woodstove emissions data. Also, a factor was developed from the catalytic woodstove emissions data and was used to estimate emissions for catalytic and noncatalytic woodstoves.

EOM emissions data for fireplaces were not available. To develop an EOM emission factor for fireplaces, the ratio of the EOM factor to the 16-PAH emission factor for conventional woodstoves was calculated and applied to the 16-PAH emission factor for fireplaces. The development of 16-PAH emission factors is described in Appendix B.

Annual EOM emissions for conventional woodstoves =
33.8 million tons * 72% * 95% * 19.61 lb/ton = 453,257,725 lb

Annual EOM emissions for catalytic/noncatalytic woodstoves =
33.8 million tons * 72% * 5% * 7.41 lb/ton = 9,019,949 lb

Annual EOM emissions for fireplaces =
33.8 million tons * 28% * (19.61/0.718) * 0.037 lb/ton = 9,483,939 lb

Annual EOM emissions for residential wood combustion = 471,761,612 lb
= 235,881 tons

EOM emissions factor for residential wood combustion =
471,761,612 lb/33,800,000 tons = 13.96 lb/tons

Dioxin/Furan Emissions Estimate

The dioxin/furan factors used to estimate emissions from residential wood combustion are weighted emission factors that represent fireplace and woodstove use. Dioxin/furan emission estimates attributed to residential wood combustion were based on a methodology developed by EPA's Office of Health Exposure and Assessment.[5] Using two recent studies (conducted in Switzerland and Denmark) that reported direct measurement of CDD/CDF emissions from wood stoves, an average emission factor of 2×10^{-9} lb TEQ/ton (1 ng TEQ/kg) was derived.

Annual 2,3,7,8-TCDD emissions =
33.8 million tons * 2.55×10^{-11} lb/ton = $8{,}62 \times 10^{-4}$ lb = 4.31×10^{-7} tons

Annual 2,3,7,8-TCDF emissions =

33.8 million tons * 8.9 x 10^{-10} lb/ton = 3.01 x 10^{-2} lb = 1.50 x 10^{-5} lb

Annual 2,3,7,8-TCDD TEQ emissions =

33.8 million tons * 2.0 * 10^{-9} lb/ton = 6.76 x 10^{-2} lb = 3.38 x 10^{-5} tons

Major/Area Source Assumptions

The category of residential wood consumption is assumed to be strictly an area source, with no single woodstove or fireplace emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR RESIDENTIAL WOOD COMBUSTION

1. Energy Information Administration. February, 1993. Household Energy Consumption and Expenditures 1990. DOE/EIA-0321(90).

2. Energy Information Administration. February 1993. Household Energy Consumption and Expenditures 1990, Supplement: Regional. Office of Energy Markets and End Use. DOE/EIA-0321(90/S). pp. 30, 115, 205, and 297.

3. Letter and attachments from David Menotti, Shaw, Potts, and Trowbridge, to Anne Pope, U.S. Environmental Protection Agency. Comments to the draft 112(c)(6) emissions inventory report. November 27, 1996.

4. Steeber, Raymond, S. 1991. Comparison of Emissions and Organic Fingerprints from Combustion of Oil and Wood. Presentation at 84th Annual Meeting and Exhibition of Air and Waste Management Association. Vancouver, British Columbia. 91-136.2.

5. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. pp. 3-143-3-146.

A.25 Iron and Steel Foundries

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Level/Emission Estimates

The national activity level for iron and steel foundries for the base year 1990 is 10,199,820 tons of iron/steel product produced.[1] The national activity level estimate for ferrous foundries includes 9.15×10^6 tons of iron castings and 1.10×10^6 tons of steel castings produced by approximately 1100 foundries nationally in 1990.[1] Emission factors will be used to estimate emissions associated with the national activity data.

Assumptions on Process and Control Levels

The emission factors used to estimate emissions from iron and steel foundries were derived from one California Air Resources Board (CARB) AB-2588 facility test report.[2] The test report quantified emissions from a batch-operated cupola furnace charged with pig iron, scrap iron, steel scrap, coke, and limestone. Emission control devices in operation during the test were an oil-fired afterburner and a baghouse.

Emission Factors

Table A-17 lists the emission factors for each pollutant that were used to develop the national emissions estimate for iron and steel foundries. The dioxin/furan emission factors were derived from one CARB AB-2588 facility test report.[2] Fully speciated dioxin/furan profiles were available to calculate 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1989 scheme.[3]

TABLE A-17. IRON AND STEEL FOUNDRY EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	2.47×10^{-10}	lb/ton product
2,3,7,8-TCDF	7.92×10^{-9}	lb/ton product
2,3,7,8-TCDD TEQ	3.68×10^{-9}	lb/ton product
CDD	6.29×10^{-8}	lb/ton product
CDF	3.10×10^{-7}	lb/ton product

Major/Area Source Assumptions

Iron and steel foundries are assumed to be major sources, with all facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR IRON AND STEEL FOUNDRIES

1. Iron and Steel, In: Mineral Commodity Summaries. 1991. U.S. Department of The Interior, Bureau of Mines. Washington, DC.

2. Emissions Measurements of a Cupola Baghouse for AB-2588 Toxics. December 1990. Confidential Report No. ERC-61. California Air Resources Board, Sacramento, California.

3. U.S. Environmental Protection Agency. 1989. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and -Dibenzofurans (CDDs and CDFs) and 1989 Update. EPA-625/3-84-016. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC. 98 pp.

A.26 Secondary Copper Smelters

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDD TEQ

National Activity Level/Emission Estimates

The activity data for secondary copper smelters for the base year 1990 is available only on a national level. Test data were available for 2,3,7,8-TCDD for one U.S. facility, and it was not possible to develop an emission factor from the test data. The 2,3,7,8-TCDD and 2,3,7,8-TCDD TEQ national emission estimates therefore represent only one facility.[1]

Assumptions on Process and Control Levels

The emission factors that were used in the past to estimate emissions from secondary copper smelters were derived from test data from one U.S. facility, and it was determined that the facility is not representative of the industry.[1,2] The unit tested was a batch-fed cupola type blast furnace controlled by gas-fired afterburners and a fabric filter. The facility is not representative of the industry because at the time of testing wire burning rather than chopping was used to remove insulation.[1]

Emission Factors

Emission factors were not used to estimate emissions from this source. 2, 3, 7, 8-TCDD emissions data were used to calculate the 2, 3, 7, 8-TCDD TEQ values.[3]

Major/Area Source Assumptions

The category of secondary copper smelting is assumed to be a 25 percent major/75 percent area source, with 25 percent of all secondary copper smelters emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR SECONDARY COPPER SMELTERS

1. Research Triangle Institute. 1994. Preliminary Source Assessment for the Secondary Copper Smelting Industry. Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

2. U.S. Environmental Protection Agency. 1987. National Dioxin Study Tier 4-Combustion Sources. Final Test Report-Site 10 Secondary Copper Recovery Cupola Furnace MET-A. EPA-450/4-87-014s. Research Triangle Park, North Carolina.

3. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.27 Secondary Lead Smelters

Secondary lead smelting involves the recovery of lead from scrap automobile batteries.

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Emissions/Activity Levels

The national activity level for secondary lead smelters for the base year 1990 is 948,000 tons lead produced.[1] National emission estimates were made using emission factors and facility specific process, control technology, and production data compiled under the Secondary Lead Smelting NESHAP program. The NESHAP estimates for dioxins/furans emissions are as follows:

- 2,3,7,8-TCDD - 1.95×10^{-3} lb/yr
- 2,3,7,8-TCDF - 1.20×10^{-2} lb/yr
- 2,3,7,8-TCDD TEQ - 8.49×10^{-3} lb/yr
- Total CDD - 1.27×10^{-1} lb/yr
- Total CDF - 2.50×10^{-1} lb/yr

Assumptions on Process and Control Levels

There are three principal furnace types in operation at secondary lead smelting facilities in the U.S., the blast furnace, the rotary furnace and the reverberatory furnace. Emission control technologies used include baghouses or a baghouse with a scrubber.

Emission Factors

Table A-19 lists the emission factors for each pollutant that were used to develop the national emissions estimate for secondary lead smelters. The dioxin/furan emission factors were derived from industry test reports of three facilities representing the three principal furnace types in use.[2,3,4] Controlled (baghouse and scrubber) and uncontrolled (baghouse only) emission factors for each furnace type were input into the NESHAP industry database to estimate State level emissions. Fully speciated dioxin/furan profiles were available to calculate 2,3,7,8-TCDD toxic equivalency.[5]

Major/Area Source Assumptions

The category of secondary lead smelting is assumed to be a 80 percent major/20 percent area source, with 80 percent of all secondary lead smelters emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.[6]

TABLE A-19. SECONDARY LEAD SMELTING EMISSION FACTORS (LB/TON LEAD PRODUCED)

Pollutant	Baghouse Outlet	Scrubber Outlet
Rotary Furnace		
2,3,7,8-TCDD	3.16×10^{-10}	3.96×10^{-10}
2,3,7,8-TCDF	2.00×10^{-9}	2.00×10^{-9}
2,3,7,8-TCDD TEQ	1.42×10^{-9}	1.21×10^{-10}

TABLE A-19. SECONDARY LEAD SMELTING EMISSION FACTORS (LB/TON LEAD PRODUCED) (Continued)

Pollutant	Baghouse Outlet	Scrubber Outlet
Total CDD	1.49×10^{-8}	1.85×10^{-9}
Total CDF	5.16×10^{-8}	5.16×10^{-8}
Blast Furnace		
2,3,7,8-TCDD	4.46×10^{-9}	5.38×10^{-10}
2,3,7,8-TCDF	1.85×10^{-8}	1.97×10^{-9}
2,3,7,8-TCDD TEQ	1.76×10^{-8}	1.68×10^{-9}
Total CDD	2.94×10^{-7}	2.26×10^{-8}
Total CDF	5.10×10^{-7}	4.74×10^{-8}
Blast/Reverb Furnace		
2,3,7,8-TCDD	1.48×10^{-10}	1.75×10^{-10}
2,3,7,8-TCDF	8.34×10^{-9}	2.88×10^{-9}
2,3,7,8-TCDD TEQ	2.68×10^{-9}	8.14×10^{-10}
Total CDD	1.12×10^{-8}	1.42×10^{-8}
Total CDF	7.66×10^{-8}	3.16×10^{-8}

REFERENCES FOR SECONDARY LEAD SMELTERS

1. Larrabee, D.A. Lead. 1991. In: U.S. Industrial Outlook 1991. U.S. Department of Commerce, International Trade Administration, Washington, DC.

2. U.S. Environmental Protection Agency. 1992. Draft Emission Test Report. HAP Emission Testing on Selected Sources at a Secondary Lead Smelter. Tejas Resources, Inc. Prepared by Roy F. Weston, Inc. Contract No. 68-D1-0104.

3. U.S. Environmental Protection Agency. 1993. Draft Emission Test Report. HAP Emission Testing on Selected Sources at a Secondary Lead Smelter. Schuylkill Metals Corporation. Prepared by Roy F. Weston, Inc. Contract No. 68-D1-0104.

4. U.S. Environmental Protection Agency. 1993. Draft Emission Test Report. HAP Emission Testing on Selected Sources at a Secondary Lead Smelter. East Penn Manufacturing Company. Prepared by Roy F. Weston, Inc. Contract No. 68-D1-0104.

5. U.S. Environmental Protection Agency. 1989. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs) and 1989 Update. EPA-625/3-84-016. Office of Health and Environmental Assessment, Washington, DC. 98 pp.

6. U.S. Environmental Protection Agency. 1995. Secondary Lead Smelting Background Information Document for Promulgated Standards. EPA-453/R-95-008b. Research Triangle Park, North Carolina.

A.28 Primary Aluminum Production

Pollutants Addressed

- EOM

Emission Estimates

The annual emissions estimate was developed from data presented in the background documentation for the development of the Primary Aluminum Industry MACT.[1] The document presents baseline emissions estimates which are representative of 1990 emissions.[2]

The baseline emission estimates are based on model processes. Data provided from industry information collection requests were used to develop model processes that represent the major production processes in the industry (aluminum production, paste production, and anode baking), and the annual production rates and emission factors for each process. The aluminum production process was divided into the four different types of potlines used in the industry: center-worked prebake; side-worked prebake; horizontal stud Soderberg; and, vertical stud Soderberg. EOM emissions for the individual processes were estimated using the appropriate activity data and emission factors. The individual estimates were summed to obtain an overall estimate for primary aluminum production. The activity data, emission factor, and emissions estimate for each process are presented in the following table.

1990 emissions will be reduced by 50 percent after the primary aluminum industry MACT is implemented.

Major/Area Source Assumptions

The category of primary aluminum production is assumed to be a major source, with all primary aluminum smelters emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. The EPA's Documentation for the Development of the Initial Source Category List[3] also lists "Primary Aluminum Production" as a major source category.

Process	Activity Data	Emission Factor	EOM Emissions (tons)
Aluminium Production[a]			
CWPB	3,124,500 tons aluminum produced	1.38 lb/ton aluminum produced	2,161
SWPB	500,000 tons aluminum produced	0.30 lb/ton aluminum produced	75
HSS	447,000 tons aluminum produced	3.74 lb/ton aluminum produced	835
VSS	435,000 tons aluminum produced	0.47 lb/ton produced	103
Anode Bake Furnaces	2,032,000 tons anode produced	0.55 lb/ton anode produced	555
Paste Production	2,722,720 tons paste produced	0.11 lb/ton paste produced	147
Total EOM Emissions (tons)			3,876

[a]CWPB = Center-worked prebake
SWPB = Side-worked prebake
VSS = Vertical Stud Soderberg
HSS = Horizontal Stud Soderberg

REFERENCES FOR PRIMARY ALUMINUM PRODUCTION

1. Primary Aluminum Industry: Technical Support Document for Proposal MACT Standards. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. July 1996.

2. Data provided by Steve Fruh, U.S. Environmental Protection Agency, to Jack Johnson, Eastern Research Group, Inc. on 1990 emissions from the Primary Aluminum Industry. January 7, 1996.

3. U.S. Environmental Protection Agency. 1992. Documentation for Developing the Initial Source Category List. Final Report. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-450/3-91-030. p. 3-4.

A.29 Secondary Aluminum Production

Pollutants Addressed

- 2,3,7,8-TCDD TEQ

Emission Estimates

A national 2,3,7,8-TCDD TEQ emissions estimate for secondary aluminum production was developed from data provided by The Aluminum Association to the U.S. EPA.[1,2] Data that could be used to develop mass emissions estimates of dioxins/furans were not available.

The emissions estimate is based on model processes that represent the main processes and emission controls used by the secondary aluminum industry. An annual 2,3,7,8-TCDD TEQ emission rate was developed for each process/control configuration, based on 8,760 hours of operation per year. In addition, a utilization factor (the percent of time that the process is actually in operation) was developed for each configuration and the number of process units for each configuration were identified. To estimate actual annual TEQ emissions from a process/control, the TEQ emission rate (lb/yr) was multiplied by the utilization factor (percent or fraction) and the number of process units in operation. The data used to develop the emissions estimates are presented in Table A-20.

Major/Area Source Assumptions

The category of secondary aluminum smelting is assumed to be a 50 percent major/50 percent area source, with 50 percent of all secondary aluminum delaquering furnaces located at facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

Process	Controls	TEQ Emission Rate (lb/yr)[a]	Utilization Factor[b]	Number of Units	TEQ Emissions (lbs)[c]
Scrap Dryers	Afterburner	0.013	0.8	19	0.1976
Scrap Dryers	Afterburner/ Baghouse	0.0059	0.8	5	0.0236
Delacquering Units	Afterburner	0.00015	0.8	21	0.0025
Foundry Side-wells	Baghouse	0.00051	0.7	41	0.0145
Foundry Side-wells	Uncontrolled	0.00425	0.7	39	0.1161
Nonfoundry Side-wells	Uncontrolled	0.000056	0.8	8	0.00036
Other Reverberatory Furnaces	Uncontrolled	0.000056	0.8	564	0.0253
Total Emissions					0.38

[a]Emission rate based on 8,760 hours/year of operation.
[b]Percent of time process is actually operating.
[c]Emission rate (lb/yr) * Utilization factor (unitless) * Number of units.

REFERENCES FOR SECONDARY ALUMINUM SMELTERS

1. Memorandum from Bob Strieter, The Aluminum Association, to Juan Santiago, U.S. Environmental Protection Agency. Annual Dioxin Emissions for Secondary Aluminum Production. May 17, 1996.

2. Memorandum from Juan Santiago, U.S. Environmental Protection Agency, to Jack Johnson, Eastern Research Group, Inc. New Dioxin/Furan Emissions Data Received from The Aluminum Association. January 22, 1997.

A.30 Drum and Barrel Reclamation/Incineration

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Level/Emission Estimates

The national activity level for drum and barrel reclamation/incineration for the base year 1990 is 4,600,000 drums (55-gallon) burned.[1] National emission estimates were made using emission factors and the reported total number of drums thermally reclaimed.

Assumptions on Process and Control Levels

The emission factors used to estimate emissions from drum and barrel reclamation/incineration were derived from test data from one U.S. facility operating a tunnel furnace controlled by a high temperature afterburner.

Emission Factors

Table A-21 lists the emission factors for each pollutant that were used to develop the national emissions estimate for drum and barrel reclamation/incineration.[2] The dioxin/furan emission factors were derived from one facility test report conducted under the Tier 4 National Dioxin Survey. 2,3,7,8-TCDD/TCDF isomer specific emission factors and homologue totals were used in calculating 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1986 scheme.[3]

TABLE A-21. DRUM AND BARREL RECLAMATION EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	4.61×10^{-9}	lb/10^3 drum
2,3,7,8-TCDF	8.05×10^{-8}	lb/10^3 drum
2,3,7,8-TCDD TEQ	1.09×10^{-7}	lb/10^3 drum
CDD	4.48×10^{-7}	lb/10^3 drum
CDF	2.43×10^{-6}	lb/10^3 drum

Major/Area Source Assumptions

The category of drum and barrel reclamation/incineration is assumed to be strictly an area source, with no drum and barrel reclamation/incineration facilities emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR DRUM AND BARREL RECLAMATION/INCINERATION

1. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. p. 3-69.

2. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

3. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.31 Coke Ovens

Pollutants Addressed

- EOM

National Activity/Emission Levels

The 1990 national activity level for the coke production category as reported by EIA is 28.9 million tons of coke produced.[1] The national activity level represents coke production from furnace coke plants (25.2 million tons of coke produced per year) and merchant coke plants (3.7 tons of coke produced per year). Furnace plants are owned by or affiliated with iron- and steel-producing companies that produce coke primarily for consumption in their own blast furnaces. Merchant plants produce coke for sale on the open market, selling most of their product to firms engaged in blast furnace, foundry, and nonferrous operations.

Assumptions on Processes and Control Levels

The emission factor presented below represents emissions from charging operations, leaking doors, charging lids, and oven offtakes, all of which are emission points associated with the coking process. There are other potential EOM emission points within a coke oven by-product plant (e.g., quenching, tar decanting and storage, and pushing operations), but there was not suitable emission factor data available to estimate emissions from these points.

The emissions from each of the points considered in this inventory are fugitive emissions and are highly dependent on the maintenance of the coke ovens and worker practice. The emission rates for doors are dependent on how well the seals around the doors are maintained. The rates of emissions for lids and offtakes are dependent on worker practice in applying sealants around the gaps, the size of the gaps, and pressure fluctuations around the coke oven. Charging emission rates are a function of the time over which the coal is loaded into the oven, the pressure fluctuations around the oven, and the gap size around the charging ports.

The emission factor used in this report reflects an average between well-controlled and poorly controlled coke ovens. The EPA report[2] from which this emission factor was developed created a set of three model coke oven batteries representing coke ovens that produce foundry coke, older coke ovens producing blast furnace coke built before 1972, and newer coke ovens producing blast furnace coke built between 1972 and 1987 (Model 1, Model 2, and Model 3, respectively). Associated operating parameters such as charging rate, percent leaking doors, percent leaking lids, and cycle times were built into the models. The database on which the models were built included 528 observations at 15 coke oven batteries.

Emission Factors

The emission factor for EOM that was used in this inventory is 0.047 lb EOM/ton of coke produced. This EOM factor represents topside emissions from coke ovens as described above. This emission factor represents emissions associated with charging operations, door leaks, leaks from charging lids, and from oven offtakes. As described above, this emission factor represents an average between a well-controlled and poorly controlled coke oven.

The EOM emission factor was developed from four separate emission factors presented in the EPA's coke ovens document.[3] The four emission factors (one for each of the four emission points included in this inventory) were presented in that document as emission rates of benzene soluble organics (BSO) for each of the three model coke oven batteries that were created. Though not chemically identical, for the purposes of this study, the BSO does not include the very polar material, but does include most of the POM fraction of the sample. BSO is considered equivalent to EOM. A single weighted EOM emission factor was developed by adding all four emission factors together within a model battery and then weighting the single model battery emission factors based on the percentage of national coke oven capacities associated with each model.[4] These percentages are: 54 percent Model 3, 39 percent Model 2, and 7 percent for Model 1.

Major/Area Source Assumptions

The category of coke oven production is assumed to consist entirely of major sources, with each facility typically emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. This is a reasonable assumption considering that the majority of the coke production facilities are associated with iron and steel producing plants and that "coke oven emissions" are identified as a specific HAP on the CAAA list of HAPs.

REFERENCES FOR COKE OVENS

1. Energy Information Administration. Coke Plant Report - Quarterly. Form EIA-5. Coke and Breeze Production at Coke Plants. 1990 Year End Estimate.

2. U.S. Environmental Protection Agency. April 1987. Coke Oven Emissions from Wet-Coal Charged By-product Coke Oven Batteries-Background Information for Proposed Standards. EPA-450/3-85-028a. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. pp. 6-1 to 6-9.

3. U.S. Environmental Protection Agency. April 1987. Coke Oven Emissions from Wet-Coal Charged By-product Coke Oven Batteries-Background Information for Proposed Standards. EPA-450/3-85-028a. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. p. 7-12.

4. U.S. Environmental Protection Agency. June 22, 1993. Personal communication between Joe Mangino, Radian, and Marvin Branscome, Research Triangle Institute. Coke Capacities.

A.32 Onroad Mobile Sources

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF
- EOM

National Activity Levels

The Federal Highway Administration's (FHWA) estimated 1990 national activity level for onroad mobile sources is 2,147 x 10^9 vehicle miles of travel (VMT).[1] This national activity level estimate was developed from the 1990 annual Highway Performance Monitoring System (HPMS) reports from each State in the nation; the HPMS reports are the standardized format for reporting vehicle activity levels expressed as VMT to the FHWA. The VMT estimates account for travel by passenger cars, trucks, and motorcycles on all urban and rural roadways within each State.

Assumptions on Processes and Control Levels

The emission factors developed for this category reflect the level of pollution control and the fuel type for the vehicles from which the emissions were originally sampled.

The EOM emission factor represents a composite, weighted emission factor: the emission rates from a light duty gasoline-powered vehicle with catalyst, three diesel-powered passenger vehicles, and two heavy-duty diesel vehicles (truck and bus) were combined using the weighting fractions based on the latest VMT mix distribution for these vehicles as calculated in EPA's MOBILE5a model.[2,3,4] Unleaded fuel was used in the light-duty gasoline-powered vehicle; the diesel vehicles used No. 2 diesel fuel. The vehicles were operated under simulated driving conditions on a chassis dynamometer.

The 7-PAH and 16-PAH emissions were estimated based on guidance received from EPA's Office of Mobile Sources (OMS).[5] The OMS guidance directed that emissions should be estimated by speciating a MOBILE5 model total organic gases (TOG) output to produce a benzo(a)pyrene (BaP) emission factor. The BaP factor was then speciated to produce 7-PAH and 16-PAH emission factors. This process was performed separately for areas which have inspection/maintenance (I/M) programs and those that do not. The emission factors for each area were then combined to produce total fleet emission factors, which were in turn applied to 1990 national VMT data to estimate national emissions. The data used by OMS to produce the factors and national emissions are shown in Table A-22a.

Separate dioxin/furan emission factors were derived for unleaded gasoline powered vehicles, (0.36 pg TEQ/km, for a national annual emission range of 0.4 to 4.1 g TEQ/yr), leaded gasoline powered vehicles (range of 1.1 to 108 pg TEQ/km, for a national annual emission range of 0.2 to 19 g TEQ) and diesel powered vehicles. (0.5 ng TEQ/km, for a national annual emission range of 27 to 270 g TEQ/yr).[7]

The VMT mix distribution in MOBILE5a represents the national average distribution of VMT amongst eight gasoline and diesel vehicle classes. The combined fraction for gasoline vehicles in the MOBILE5a distribution is 94 percent; for diesel vehicles it is 6 percent. According to EIA, leaded gasoline accounted for only 1.5 percent of total gasoline supplies in 1992.[8] Since there are separate EOM emission factors for light-duty and heavy-duty diesel vehicles, the specific MOBILE5a distributions

TABLE A-22a. ONROAD VEHICLE 7-PAH AND 16-PAH EMISSION ESTIMATES

Areas with no I/M											
	TOG EF[6] (g/mile) A	THC/TOG Conversion Factors B	THC EF (g/mile) C (A*B)	VMT mix[6] D	Weighted THC EF (g/mile) E (C*D)	B(a)P/THC Ratio[5] (ug/g) F	B(a)P EF (ug/mile) G (E*F)	Speciation Factor[5] 7-PAH/B(a)P H	7-PAH EF (ug/mile) I (G*H)	Speciation Factor[5] 16-PAH/B(a)P J	16-PAH EF (ug/mile) K (G*J)
LDGV	2.39	0.988	2.36	0.655	1.55	0.27	0.418	7.0	2.923	12.36	5.162
LDGT1	3.19	0.988	3.15	0.161	0.51	0.27	0.137	7.0	0.959	12.36	1.694
LDGT2	4.65	0.988	4.59	0.082	0.38	0.27	0.102	7.0	0.712	12.36	1.257
HDGV	8.68	0.988	8.58	0.031	0.27	0.27	0.072	7.0	0.503	12.36	0.887
LDDV	0.73	0.953	0.70	0.009	0.01	1.12	0.007	15.7	0.110	54.92	0.385
LDDT	1.05	0.953	1.00	0.002	0.00	1.12	0.002	15.7	0.035	54.92	0.123
HDDV	3.54	0.967	3.42	0.052	0.18	1.12	0.199	15.7	3.130	54.92	10.948
MC	2.65	0.988	2.62	0.008	0.02	0.27	0.006	7.0	0.040	12.36	0.070
Total				1					8.412		20.526

TABLE A-22a. ONROAD VEHICLE 7-PAH AND 16-PAH EMISSION ESTIMATES (CONTINUED)

Areas with I/M

	TOG EF[6] (g/mile) A	THC/TOG Conversion Factors B	THC EF (g/mile) C (A*B)	VMT mix[6] D	Weighted THC EF (g/mile) E (C*D)	B(a)P/THC Ratio[5] (ug/g) F	B(a)P EF (ug/mile) G (E*F)	Speciation Factor[5] 7-PAH/B(a)P H	7-PAH EF (ug/mile) I (G*H)	Speciation Factor[5] 16-PAH/B(a)P J	16-PAH EF (ug/mile) K (G*J)
LDGV	1.83	0.988	1.81	0.655	1.18	0.27	0.320	7.0	2.238	12.36	3.953
LDGT1	3.19	0.988	3.15	0.161	0.51	0.27	0.137	7.0	0.959	12.36	1.694
LDGT2	4.65	0.988	4.59	0.082	0.38	0.27	0.102	7.0	0.712	12.36	1.257
HDGV	8.68	0.988	8.58	0.031	0.27	0.27	0.072	7.0	0.503	12.36	0.887
LDDV	0.73	0.953	0.70	0.009	0.01	1.12	0.007	15.7	0.110	54.92	0.385
LDDT	1.05	0.953	1.00	0.002	0.00	1.12	0.002	15.7	0.035	54.92	0.123
HDDV	3.54	0.967	3.42	0.052	0.18	1.12	0.199	15.7	3.130	54.92	10.948
MC	2.65	0.988	2.62	0.008	0.02	0.27	0.006	7.0	0.040	12.36	0.070
	Total			1					7.727		19.317
				Fleet EF for all areas (ug/mile)[a]:	7-PAH 7.95	16-PAH 19.704					
				1990 National VMT[1]:	2.147e+12						
					National Emission Estimate (tons/year)		7-PAH 18.81	16-PAH 46.63			

[a]The fleet Ef for all areas is a composite weighting based on percentage of total fuel use (32% for areas with no I/M and 68% for areas with I/M).

of 5 percent heavy-duty diesel and 1 percent light-duty diesel vehicles are used in addition to the gasoline vehicle fraction to calculate a weighted emission factor for EOM.

Emission Factors

Table A-22b lists the emission factors for EOM and dioxins/furans that will be used in the inventory. Weighted EOM emission factors were calculated based on the distribution of vehicle types described above. One composite EOM emission factor will be used to represent a fleet-wide average emission factor. It should be noted that this emission factor is derived from a limited number of older vehicles, which is not representative of the current vehicle fleet.

TABLE A-22b. ONROAD MOBILE SOURCE EMISSION FACTORS

Pollutant	Emission Factor	Units
7-PAH	1.753×10^{-5}	lb/thousand vehicle miles
16-PAH	4.344×10^{-5}	lb/thousand vehicle miles
EOM	5.20×10^{-2}	lb/thousand vehicle miles
2,3,7,8-TCDD	3.60×10^{-12}	lb/thousand vehicle miles
2,3,7,8-TCDF	5.65×10^{-11}	lb/thousand vehicle miles
2,3,7,8-TCDD TEQ	8.85×10^{-11}	lb/thousand vehicle miles

Major/Area Source Assumptions

The category of onroad mobile source is assumed to be entirely an area source category since there is no single point source emissions associated with this category.

REFERENCES FOR ONROAD MOBILE SOURCES

1. U.S. Department of Transportation. Highway Statistics 1990. Federal Highway Administration. FHWA-PL-91-003.

2. Albert, Roy E., et. al. 1983. Comparative Potency Method for Cancer Risk Assessment: Application to Diesel Particulate Emissions. Risk Analysis, Volume 3, No. 2. p. 105.

3. Lewtas, Joellen. 1989. Carcinogens and Mutagens in the Environment. Chapter 4, Combustion Emissions: Characterization and Comparison of Their Mutagenic and Carcinogenic Activity, Volume V. p. 68.

4. U.S. Environmental Protection Agency. March 26, 1993. MOBILE5a Emission Factor Model. U.S. Environmental Protection Agency, Office of Mobile Sources. Ann Arbor, Michigan.

5. Memorandum from Pam Brodowicz, U.S. Environmental Protection Agency, Office of Mobile Sources (OMS) to Eric Ginsburg and David Mobley, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. "Determining POM/PAH Emission Factors for Mobile Sources." December 19, 1996.

6. U.S. Environmental Protection Agency. 1993. Motor Vehicle-Related Air Toxics Study. EPA-420-R-93-005. Office of Mobile Sources. Ann Arbor, Michigan.

7. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. pp. 3-134 - 3-142.

8. Energy Information Agency. 1993. Monthly Energy Review - January 1993. DOE/EIA-0035(93/01). U.S. Department of Energy, Office of Energy Markets and End Use, Washington, DC.

A.33 **Non-road Vehicles**

Pollutants Addressed

An emission estimate for EOM will be included in the inventory for non-road mobile sources.

National Activity Levels

The estimated 1990 national activity level for non-road mobile sources is 5.98×10^9 gallons of diesel fuel.[1] This national activity level estimate was developed from the EPA Office of Mobile Sources' (OMS) 1990 annual estimates of non-road source activity reported for ozone nonattainment areas. The national activity level presented above represents the two equipment class categories of agricultural and construction diesel-powered equipment. In order to develop a national activity level estimate for these categories, the EPA estimates for 24 ozone nonattainment areas were extrapolated to the nationwide level using a population adjustment factor. This is the standard procedure described in EPA guidance[2] for the development of non-road mobile source inventories for the 1990 State Implementation Plans (SIPs).

Assumptions on Processes and Control Levels

The activity levels calculated for the EPA non-road inventories for the 24 ozone nonattainment areas reflect national average use parameters for such parameters as equipment type, horsepower rating, and the hours of usage throughout the year. Seasonal adjustment factors were used in deriving these activity levels; for example, activity for the agricultural equipment category is not assumed to be consistent throughout the year, but rather is higher during the spring, summer, and fall relative to the winter. The annual activity level is the sum of all the seasonal activity levels.

All the activity levels are for diesel-powered engines in each of the equipment classes. The agricultural equipment class includes equipment such as tractors, combines, tillers, and balers; the construction equipment category includes equipment such as pavers, rollers, dozers, and loaders. While there are gasoline-powered non-road equipment within these classes, these are not part of this current inventory due to the lack of suitable emission factor data. However, approximately 70 percent of the fuel consumed by agricultural equipment and 85 percent of the fuel consumed by construction equipment is diesel.[3]

The EOM emission factor is based on emission sampling[4] of the exhaust of a heavy-duty diesel engine from a Caterpillar tractor. It should be noted that this emission factor which is for agricultural and construction equipment is based on a single engine test which limit the accuracy of the emission estimates.

Emission Factors

The EOM emission factor that was used in the inventory is 8.4×10^{-3} lb EOM/gallon of diesel fuel consumed. This emission factor was developed from the emission factor listed for soluble organic fraction (SOF) for a Caterpillar 320B engine.[4] The emission factor for SOF in that study that was reported in units of mg per mile (475 mg SOF/mile). For the purpose of this inventory, it was assumed that diesel engine tested had fuel efficiency rate of 8 miles per gallon of diesel fuel consumed. This translates into an emission factor of 3.8 g, or 8.4×10^{-3} lb, SOF per gallon of diesel fuel consumed. The SOF is equivalent to EOM.[5]

Major/Area Source Assumptions

The category of non-road mobile sources is assumed to be entirely an area source category since there is no single point of emissions associated with this category that results in emissions greater than 10 tons per year of one HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR NON-ROAD VEHICLES

1. U.S. Environmental Protection Agency. November 1991. Non-road Engine and Vehicle Emission Study (associated spreadsheet emissions data updated and revised in October 1992). 21A-2001. Office of Air and Radiation, Washington, DC.

2. U.S. Environmental Protection Agency. 1992. Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources. EPA-450/4-81-026d (revised). Office of Mobile Sources, Anne Arbor, Michigan. pp. 98 - 115.

3. U.S. Environmental Protection Agency. July 1989. Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources. EPA-450/4-81-026d (revised). Office of Mobile Sources, Anne Arbor, Michigan. pp. 3-3 and 3-5.

4. Zweidinger, Roy B. 1982. Emission Factors from Diesel and Gasoline Powered Vehicles: Correlation with the Ames Test. U.S. Environmental Protection Agency, Mobile Source Emissions Research Branch, Research Triangle Park, North Carolina. pp. 90 - 92.

5. Personal communication between Joe Mangino, Radian, and Joellen Lewtas, U.S. Environmental Protection Agency, Health Effects Research Laboratory. August 4, 1993. EOM Emission Factors for Diesel Engines.

A.34 Turbines and Engines - Distillate Oil Internal Combustion

Pollutants Addressed

- EOM

National Activity Levels

The national activity level for distillate fuel oil consumption for stationary internal combustion in the base year 1990 is 56,224,000 barrels of distillate fuel oil.[1] The national activity level reported for distillate fuel includes petroleum products known as No. 1, No. 2, and No.4 fuel oils and No. 1, No. 2, and No. 4 diesel fuels. These fuels are consumed in diesel-fueled engines and turbines. The national estimate of distillate fuel consumption for stationary internal combustion sources provided above represents the national estimate of distillate fuel consumption as reported by EIA, excluding the diesel fuel consumption associated with external combustion sources (i.e., residential furnaces, commercial and industrial boilers) and transportation sources (i.e., onroad and non-road mobile sources). Sales data reported by the EIA in its 1990 annual of Fuel Oil and Kerosene Sales[2] were used to divide the distillate fuel consumption amongst the stationary internal, external, and transportation sources.

Assumptions on Process and Control Levels

The engines and turbines that were part of the EPA's emissions sampling program[3] from which the emission factors used in this inventory were developed are all uncontrolled sources. Therefore, there are no assumptions regarding control levels for this source category, and the final emission estimates reflect uncontrolled emission rates.

Emission Factors

The emission factor for EOM from distillate oil-fired engines and turbines that was used in this inventory is 130.2 lb EOM/10^3 barrels of distillate fuel consumed. The emission factor data were compiled from the EPA's emissions sampling program for internal combustion sources (5.4 ng/Joule of thermal input for turbines and 34 ng/Joule of thermal input for engines).[3] The EOM factor presented here is a weighted emission factor which represents both engine and turbine use. The engine and turbine weighting factors were based on the relative distillate fuel consumption of these two types of internal combustion sources as reported in the EPA's Environmental Assessment of Stationary Internal Combustion Systems.[4] Based on 1985 nationwide distillate consumption estimates reported in this assessment, the relative consumption for stationary internal combustion sources is 85 percent turbines and 15 percent engines. Turbines typically are designed to produce larger amounts of energy than engines and therefore are expected to account for a larger proportion of the distillate consumption for this category.

Major/Area Source Assumptions

The category of distillate-fueled stationary internal combustion sources is assumed to consist of 70 percent major sources and 30 percent area sources. While most single engines or turbines do not emit more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs, these units are often co-located at industrial facilities and electric utility plants that are major sources. The 70 percent major/30 percent area split was made considering that the majority of the turbines are associated with power generating plants that are primarily classified as major sources (see Sections A.6 through A.8), and assuming that approximately 50 percent of the industrial sector consists of major sources.

REFERENCES FOR TURBINES AND ENGINES - DISTILLATE OIL INTERNAL COMBUSTION

1. Energy Information Administration. May 1992. State Energy Data Report, Consumption Estimates 1960-1990. DOE/EIA-0214(90). Office of Energy Markets and End Use, Washington, DC. pp. 22, 478.

2. Energy Information Administration. October 1991. Fuel Oil and Kerosene Sales 1990. DOE/EIA-0535(90). Office of Energy Markets and End Use, Washington, DC. p. 9.

3. U.S. Environmental Protection Agency. Emissions Assessment of Conventional Stationary Combustion Systems, Volume II. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 143 - 146.

4. U.S. Environmental Protection Agency. September 1991. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. PB82-109414. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 34.

A.35 Turbines - Natural Gas Internal Combustion

Pollutants Addressed

- EOM

National Activity Levels

The national activity level for natural gas-fired turbines within the stationary internal combustion source category in the base year 1990 is 562 x 10^9 cubic feet of natural gas.[1] This national activity level includes natural gas consumed by gas-fired turbines in the industrial and electric utility sectors and is derived from the total national consumption of natural gas as reported by EIA for 1990. Based on information from the EPA's Environmental Assessment of Stationary Internal Combustion Systems[2] approximately 3 percent of the total national natural gas consumption in 1985 was associated with gas-fired turbines; this percentage was used to calculate the fraction of the 1990 natural gas consumption for gas-fired turbines.

Assumptions on Processes and Control Levels

The turbines that were part of the emissions sampling program from which the emission factors used in this inventory were developed are all uncontrolled sources. Therefore, there are no assumptions regarding control levels for this source category, and the final emission estimates reflect uncontrolled emission rates.

Emission factor data were available for two types of turbines; industrial and electric utility. In order to develop a weighted emission factor for this category, the 1985 relative consumption of natural gas for industrial and electric utility turbines from the EPA's Environmental Assessment of Stationary Internal Combustion Systems[3] was used. Based on this consumption data, approximately 84 percent of natural gas consumption for gas-fired turbines occurs in the industrial sector, while 16 percent occurs in the electric utility sector. These percentages reflect the general tendency for the electric utility industry to use gas turbines primarily for peaking power than continuous power. These percentages were used to derive the weighted emission factor presented below.

Emission Factors

The emission factor for EOM that was used for natural gas-fired turbines in the inventory is 2.63×10^{-3} lb EOM/10^{3} cubic feet of natural gas consumed. The EOM factor is a weighted emission factor based on the relative industrial and electrical utility sector use described above. The emission factors from the EPA's assessment of this category (2.30 ng/Joule of thermal input for electric utility turbines and 0.86 ng/Joule of thermal input for industrial turbines)[4] were converted to units of lb EOM per 10^{3} cubic feet of natural gas consumed by using the thermal conversion factor of 1.03×10^{3} Btu per cubic foot of natural gas.[5]

Major/Area Source Assumptions

The category of natural gas-fired stationary internal combustion sources is assumed to consist of 60 percent major sources and 40 percent area sources. While no single turbine emits more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs, these units are co-located at industrial facilities and electric utility plants that are major sources. Assuming that 50 percent of the industrial sector consists of major sources and 100 percent of the electric utilities are major sources, then based on the relative consumption of natural gas for these two sectors as described above, the estimate of 60 percent major sources and 40 percent area sources was derived.

REFERENCES FOR TURBINES - NATURAL GAS INTERNAL COMBUSTION

1. Energy Information Administration. May 1992. State Energy Data Report, Consumption Estimates 1960-1990. DOE/EIA-0214(90). Office of Energy Markets and End Use, Washington, DC. p. 22.

2. U.S. Environmental Protection Agency. February 1979. Emissions Assessment of Conventional Stationary Combustion Systems, Volume II: Internal Combustion Sources. EPA-600/7-79-029C. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 143 - 146.

3. U.S. Environmental Protection Agency. February 1979. Emissions Assessment of Conventional Stationary Combustion Systems, Volume II: Internal Combustion Sources. EPA-600/7-79-029C. Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. pp. 143 - 146.

4. U.S. Environmental Protection Agency. September 1991. Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report. PB82-109414. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. p. 33.

5. Energy Information Administration. May 1992. State Energy Data Report, Consumption Estimates 1960-1990. DOE/EIA-0214(90). Office of Energy Markets and End Use, Washington, DC. p. 471.

A.36 Kraft Recovery Boilers

In the Kraft pulping process, recovery boilers are used to recover chemicals used to digest wood chips. Black liquor, or spent cooking liquor, is reduced to approximately 65 percent solids in multiple effect evaporators and then combusted to recover chemicals and heat value.

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Levels/Emission Estimates

The national activity level for pulp and paper industry - black liquor combustion for the base year 1990 is 31,080,000 tons black liquor solids burned.[1] Emission factors will be used to estimate emissions associated with the national activity data.

Assumptions on Process and Control Levels

Pulp mills are required to control particulate emissions from recovery boilers according to standards in 40 CFR 60. Most commonly ESPs are employed, with few units equipped with scrubbers. The process configurations and control equipment at the six mills whose data were used to derive the average 2,3,7,8-TCDD TEQ emission factor used for this inventory were:

- 3 mills with nondirect contact evaporator (NDCE) furnace with ESP;
- 1 mill with NDCE furnace with ESP and scrubber;

- 1 mill with direct contact evaporator (DCE) furnace with ESP and scrubber; and
- 1 mill with DCE furnace with wet bottom ESP.

Emission Factors

The emission factor for 2,3,7,8-TCDD TEQ, as calculated from data collected by the National Council of the Paper Industry for Air and Stream Improvement (NCASI), is presented in Table A-23 for the pulp and paper industry - black liquor combustion.[2]

TABLE A-23. BLACK LIQUOR COMBUSTION EMISSION FACTOR

Pollutant	Emission Factor	Units
2,3,7,8-TCDD TEQ	2.2×10^{-11}	lb/ton black liquor solids

Major/Area Source Assumptions

The category of pulp and paper industry - black liquor combustion is assumed to be strictly a major source, with all Kraft pulp and paper mills emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

REFERENCES FOR KRAFT RECOVERY BOILERS

1. U.S. Environmental Protection Agency. 1992. 1990 Census of Pulp, Paper and Paperboard Manufacturing Facilities. Response to 308 Questionnaire. Part A: Technical Information. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

2. Someshwar, A.V. January 23, 1995. Summary Results of Mill Test Reports in NCASI File, Confidential. National Council of the Paper Industry for Air and Stream Improvement. Gainesville, Florida.

A.37 Pentachlorophenol (PCP) Wood Treatment

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Levels/Emission Estimates

The national activity level for PCP wood treatment for the base year 1988 is 21.6 million pounds PCP used in wood treatment operations.[1] It is assumed that 1988 activity levels accurately represent 1990 levels. An dioxin/furan emissions inventory conducted on the chlorophenol wood treatment industry in California will be used to develop emission factors and estimate national emissions associated with the national activity level.[2]

Assumptions on Process and Control Levels

Pressure treatment processes account for greater than 95 percent of the existing U.S. wood treatment facilities.[1] In PCP pressure treatment, emissions of dioxin/furan may occur by one or more of three mechanisms, in which PCP is potentially emitted. These mechanisms are:

- Emission with steam when opening the treatment cylinder;
- Evaporative losses from hot wood surfaces; and
- Fugitive emissions from pipes and fittings.[3]

Calculated emission rates from the three potential dioxin/furan emission mechanisms were included in national emissions estimate.

Emission Factors

Table A-24 lists the emission factors for each pollutant that were used to develop the national emissions estimate for PCP wood treatment. The dioxin/furan emission factors were derived using reported average emissions of five pressure treatment facilities in California and their average associated PCP consumption.[3] The emissions data used in factor development were derived using known concentrations of dioxin/furan species in PCP and calculated fugitive emission rates. Homologue totals were used in calculating 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1986 scheme.[4] It was assumed that because no 2,3,7,8-tetra congener contamination was detected in commercial PCP after dilution and mixture with co-solvents,[3] 2,3,7,8-TCDD would not be emitted to the atmosphere from the PCP wood treatment process.[3]

Major/Area Source Assumptions

The category of PCP wood treatment is assumed to be an area source, with no single PCP wood treatment facility emitting more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs.

TABLE A-24. PENTACHLOROPHENOL (PCP) WOOD TREATMENT EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	ND	---
2,3,7,8-TCDF	NA	---
2,3,7,8-TCDD TEQ	7.06×10^{-6}	lb/ton PCP
CDD	1.93×10^{-3}	lb/ton PCP

TABLE A-24. PENTACHLOROPHENOL (PCP) WOOD TREATMENT EMISSION FACTORS (Continued)

Pollutant	Emission Factor	Units
CDF	1.46×10^{-4}	lb/ton PCP

ND - Non detect.

NA - Not available.

REFERENCES FOR PENTACHLOROPHENOL (PCP) WOOD TREATMENT

1. American Wood Preservers' Association. Proceedings: Eighty-Sixth Annual Meeting. April 30-31 and May 1-2, 1990. Nashville, TN.

2. California Air Resources Board. May 15, 1987. Inventory of Chlorophenol Use in the Forest Products Industry and Investigation of Related Emissions of Chlorinated Dibenzodioxins and Dibenzofurans. Final Report. Sacramento, CA.

3. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

4. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.38 Carbon Reactivation Furnaces

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 2,3,7,8-TCDD TEQ
- CDD
- CDF

National Activity Levels/Emission Estimates

The national activity level for activated carbon consumption in water and wastewater treatment for the base year 1990 is 71,900 tons activated carbon consumed in water and wastewater treatment operations.[1] It is assumed that all activated carbon used in water and wastewater treatment operations is regenerated. Emission factors will be used to estimate emissions associated with the national level activity data.

Assumptions on Process and Control Levels

Seven carbon reactivation furnace types are in operation in the U.S. Of these, the multiple-hearth furnace is the most prevalent, with over 100 units in operation. The others, in order of descending number of units, include direct and indirect fired rotary kilns, vertical tube-type furnaces, fluidized bed furnaces, and vertical and horizontal infrared furnaces.[2] Emission control devices typically used are afterburners and water scrubbers.[3] The test reports that will be used in the inventory represent the following process configurations:

- A multiple-hearth furnace reactivating carbon used for industrial wastewater treatment, controlled by an afterburner, a sodium carbonate spray cooler, and a baghouse;[3] and

- A furnace of unknown configuration reactivating carbon used for municipal [Publicly Owned Treatment Works (POTW's)] wastewater treatment controlled by an afterburner and a scrubber.[4]

Emission Factors

Table A-25 lists the emission factors for each pollutant that were used to develop the national emissions estimate for carbon reactivation furnaces. The dioxin/furan emission factors were derived by a weighted average of emission factors from the above referenced test reports. The weighted emission factors reflect the following assumptions: 50 percent of the total amount of activated carbon thermally reactivated is from industrial uses and occurs in large multiple-hearth or similar furnace types (test 1 above); 50 percent of the total is used for municipal wastewater/potable water treatment applications and is reactivated by a processes similar to that tested in report 2 above. 2,3,7,8-TCDD/TCDF isomer specific emission factors and homologue totals were used in calculating 2,3,7,8-TCDD toxic equivalency under the U.S. EPA 1986 scheme.[5]

Major/Area Source Assumptions

The category of carbon reactivation furnaces is assumed to be a 75 percent area/25 percent major source, with 75 percent of U.S. carbon reactivation capacity located at primary carbon production facilities or chemical plants which emit more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAPs. A trend towards on-site reactivation for industries such as POTW's has been reported.[1]

TABLE A-25. CARBON REACTIVATION FURNACE EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	2.10×10^{-10}	lb/ton carbon reactivated
2,3,7,8-TCDF	1.36×10^{-9}	lb/ton carbon reactivated
2,3,7,8-TCDD TEQ	3.46×10^{-9}	lb/ton carbon reactivated
CDD	4.64×10^{-8}	lb/ton carbon reactivated
CDF	4.76×10^{-8}	lb/ton carbon reactivated

REFERENCES FOR CARBON REACTIVATION FURNACES

1. Humer, C. June 8, 1992. Activated Carbon Plant Starts for American Norit. Chemical Marketing Reporter. p. 2.

2. Byers, W.D. 1991. Charcoal/Activated Carbon. Air Pollution Engineering Manual, A.J. Buonicore and W.J. Davis, eds., van Nostrand Reinhold, New York, New York. pp. 413 - 416.

3. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

4. Emissions Measurements at Wastewater Treatment Plants for AB-2588 Toxics. April 29-May 8, 1991. Confidential Report No. 23. California Air Resources Board, Sacramento, California.

5. U.S. Environmental Protection Agency. 1986. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs). EPA-625/3-87-012. Washington, DC. 59 pp.

A.39 Forest Fires

Pollutants Addressed

- 2,3,7,8-TCDD TEQ

National Activity Levels/Emission Estimates

Dioxin/furan emission estimates attributed to forest fires were based on a methodology developed by EPA's Office of Health Exposure and Assessment, which is summarized in this section.[1] An average of 5.1 million acres of biomass are burned in wildfires each year in the U.S., based on 40 years of USDA Forest Service data. In 1989, 5.1 million acres were burned as a result of prescribed burning. Biomass consumption rates were estimated at 10.4 tons/acre for wildfires, and 8.2 tons/acre for prescribed fires. From these estimates, the national activity level for wildfires was estimated at 53 million tons of biomass consumed and for prescribed fires was estimated at 42 million tons, for a total of 95 million tons.

Applying the emission factor developed for combustion in a wood stove [which is 2.0 x 10^{-9} lb TEQ/ton biomass burned as described in Section A.24], annual TEQ emissions from forest fires were estimated at 0.19 lb (86 g), with projected range from 0.06 lb (27 g) to 0.6 lb (270 g) TEQ/yr.

Assumptions and Control Levels

No controls are used to reduce emissions from forest fires.

Major/Area Source Assumptions

Forest fires are assumed to be exclusively an area source.

REFERENCES FOR FOREST FIRES

1. U.S. Environmental Protection Agency. June 1994. Estimating Exposures to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence, and Background Exposures. External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. pp. 3-156 - 3-165.

A.40 Landfills

Pollutants Addressed

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF

National Activity Level/Emission Estimates

Approximately 67 percent of solid waste generated in the United States is landfilled, 16 percent is incinerated, and 17 percent is recycled or composted. There were an estimated 5,345 active MSW landfills in the United States in 1992. In 1990, active landfills were receiving an estimated 130 million tons (118 million Mg) of waste annually, with 55 to 60 percent reported as household waste and 35 to 45 percent reported as commercial waste.[1]

Assumptions on Processes and Control Levels

Data were obtained from one test reporting CDD/CDF emissions from a landfill equipped with waste gas flares. Although this control technique does not recover energy, it is frequently used to control emissions of landfill gas. Emission factors developed from this data are presented in Table A-26.[1]

TABLE A-26. LANDFILLS EMISSION FACTORS

Pollutant	Emission Factor	Units
2,3,7,8-TCDD	2.3×10^{-12}	lb/MMBtu
2,3,7,8-TCDF	1.76×10^{-9}	lb/MMBtu

REFERENCES FOR LANDFILLS

1. U.S. Environmental Protection Agency. 1996. Locating and Estimating Air Emissions from Sources of Dioxins and Furans. Draft Report. Research Triangle Park, North Carolina.

APPENDIX B

DOCUMENTATION OF 7-PAH AND 16-PAH NATIONAL EMISSION ESTIMATES

B.1 RESIDENTIAL WOOD COMBUSTION

Basis for Input Data

1. 7-PAH and 16-PAH emission factors were developed for conventional woodstoves, catalytic/noncatalytic woodstoves, and fireplaces. Emission factors for conventional woodstoves were developed from the individual PAH emission factors provided in AP-42 (U.S. EPA, 1995). AP-42 also provided individual PAH emission factors for catalytic and for noncatalytic woodstoves. 7-PAH and 16-PAH factors were developed for the two types, and then averaged together to obtain factors representing catalytic/noncatalytic woodstoves.

   The 7-PAH and 16-PAH emission factors for fireplaces were developed form individual PAH emissions data from two emissions tests. 7-PAH and 16-PAH factors were developed for a fireplace burning seasoned oak wood (Hall and DeAngelis, 1980) and for a fireplace burning green pine wood (Hall and DeAngelis, 1980). The 7-PAH and 16-PAH factors from the two tests were averaged together to obtain factors representing wood combustion in fireplaces.

2. The 7-PAH and 16-PAH emission factors for conventional woodstoves are 0.044 and 0.718 lb/ton, respectively.

   The 7-PAH and 16-PAH emission factors for catalytic/noncatalytic woodstoves are 0.048 and 0.627 lb/ton, respectively.

   The 7-PAH and 16-PAH emission factors for fireplaces are 0.007 and 0.037 lb/ton, respectively.

B.1 RESIDENTIAL WOOD COMBUSTION (Continued)

The national 7-PAH emissions estimates includes benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

The national 16-PAH emissions estimates include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, acenaphthene, acenaphthylene, anthracene, benzo(ghi)perylene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene.

3. 29.1 million cords (33.8 million tons) of wood combusted in residential wood combustion in 1990 (U.S. DOE, 1993a; (U.S. DOE, 1993b). The average nationwide percentage of wood consumption is 28 percent for fireplaces and 72 percent for woodstoves (U.S. DOE, 1993b). Of the 72 percent combusted in woodstoves, no more than five percent is combusted in catalytic and noncatalytic stoves (Menotti, 1996). For calculational purposes, it is assumed the remaining 95 percent (of the 72 percent) is combusted in conventional woodstoves.

<u>Calculation</u>

1. 7-PAH Annual emissions for conventional woodstoves =
33.8 million tons * 72% * 95% * 0.044 lb/ton = 1,017,245 lb

7-PAH Annual emissions for catalytic and noncatalytic woodstoves =
33.8 million tons * 72% * 5% * 0.0475 lb/ton = 57,798 lb

7-PAH Annual emissions for fireplaces =
33.8 million tons * 28% * 0.0072 lb/ton = 68,141 lb

7-PAH Annual emissions for residential wood combustion =

1,017,245 lb + 57,798 lb + 68,141 lb = 1,143,184 lb = 572 tons

7-PAH emission factor for residential wood combustion =

1,143,184 lb/33,800,000 tons = 0.034 lb/tons

2. 16-PAH Annual emissions for conventional woodstoves =

33.8 million tons * 72% * 95% * 0.718 lb/ton = 16,599,586 lb

16-PAH Annual emissions for catalytic and noncatalytic woodstoves =

33.8 million tons * 72% * 5% * 0.6265 lb/ton = 762,325 lb

16-PAH Annual emissions for fireplaces =

33.8 million tons * 28% * 0.0367 lb/ton = 347,329 lb

16-PAH Annual emissions for residential wood combustion =

16,599,586 lb + 762,325 lb + 347,329 lb = 17,709,240 lb = 8,855 tons

16-PAH emission factor for residential wood combustion =

17,709,204 lb/33,800,000 tons = 0.524 lb/ton

B.2 RESIDENTIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 0.0373 lb/1E+12 Btu (1.6E-08 g/MJ) and the 16-PAH emission factor was 2.37 lb/1E+12 Btu (1.02E-06 g/MJ). These factors were developed from the individual PAH emission factors for a natural gas-fired hot air furnace, wall space heater, and shell boiler as reported in the POM L&E document (U.S. EPA, 1996a). It was assumed that 1 cubic foot of natural gas produces 1,000 Btu.

2. The 7-PAH emission factor includes Benzo(a)pyrene.

   The 16-PAH emission factor includes Benzo(a)pyrene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, residential natural gas consumption in the United States was 4.3E+15 Btu (EIA, 1992).

Calculation

7-PAH Annual Emissions = 0.0373 lb/1E+12 Btu * 4.3E+15 Btu = 160.4 lb
= 0.0802 tons

16-PAH Annual Emissions = 2.37 lb/1E+12 Btu * 4.3E+15 Btu = 1.02E+04 lb
= 5.1 tons

B.3 RESIDENTIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.63E-04 lb/1000 gallons (6.75E-08 Mg/kL) and the 16-PAH emission factor was 6.97E-03 lb/1000 gallons (8.35E-07 Mg/kL). These factors were developed from the individual PAH emission factors for distillate (No. 2) oil-fired furnaces as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes Benz(a)anthracene and Benzo(a)pyrene. The 16-PAH emission factor includes Benz(a)anthracene, Benzo(a)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 6.04E+09 gallons of distillate fuel were consumed for residential heating use in the United States (EIA, 1992).

Calculation

7-PAH Annual Emissions =

5.63E-04 lb/1000 gal * 6.04E+09 gallons = 3,400 lb

= 1.70 tons

16-PAH Annual Emissions =

6.97E-03 lb/1000 gal * 6.04E+09 gallons = 4.21E+04 lb

= 21.0 tons

B.4 RESIDENTIAL COAL COMBUSTION

Basis for Input Data

1. The emission factors for 7-PAH were 0.0335 lb/ton (0.0168 kg/Mg) for bituminous and lignite coal and 1.41E-04 lb/ton (7.05E-05 kg/Mg) for anthracite coal. The emission factors for 16-PAH were 0.108 lb/ton (0.054 kg/Mg) for bituminous and lignite coal and 6.18E-04 lb/ton (3.09E-04 kg/Mg) for anthracite coal. These factors were developed from the individual PAH emission factors for residential coal stoves, and residential coal boilers and furnaces as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factors include: Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Phenanthrene, and Pyrene.

3. In 1990, 1.9 million tons of bituminous and lignite coal and 732,000 tons of anthracite coal were consumed in the United States (EIA, 1992).

Calculation

7-PAH bituminous and lignite coal =

0.0335 lb/ton * 1.9 million tons = 6.37E+04 lb

= 31.8 tons

7-PAH anthracite coal =

1.41E-04 lb/ton * 732,000 tons = 103 lb

= 0.0516 tons

B.4 RESIDENTIAL COAL COMBUSTION (Continued)

16-PAH bituminous and lignite coal =

0.108 lb/ton * 1.9 million ton = 2.05E+05 lb

= 102.6 tons

16-PAH anthracite coal =

6.18E-04 lb/ton * 732,000 tons = 452 lb

= 0.226 tons

B.5 UTILITY COAL COMBUSTION
UTILITY OIL COMBUSTION
UTILITY NATURAL GAS COMBUSTION

Basis for Estimate

1. 7-PAH and 16-PAH national emissions estimates for 1990 were obtained from a Research Triangle Institute (RTI) memorandum concerning hazardous air pollutant emissions from utility boilers based on information collected by the Electric Power Research Institute (Cole, 1995). These estimates are presented below along with the corresponding emission factors developed by RTI.

Utility Coal Combustion

1. The 7-PAH national emissions estimate is 0.21 tons/yr and the 7-PAH emission factor is 0.0241 lb/trillion Btu of heat input. These data include the following PAH: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

2. The 16-PAH national emissions estimate is 7.54 tons/year. The 16-PAH emission factor is 0.8747 lb/trillion Btu of heat input. These data include the following PAH: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

Utility Residual Oil Combustion

1. The 7-PAH national emissions estimate is 0.05 tons/yr and the 7-PAH emission factor is 0.0831 lb/trillion Btu of heat input. These data include the following PAH: Benz(a)anthracene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

2. The 16-PAH national emissions estimate is 0.57 tons/year. The 16-PAH emission factor is 0.9251 lb/trillion Btu of heat input. These data include the following PAH: Benz(a)anthracene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

Utility Natural Gas Combustion

1. RTI did not develop a 7-PAH national emissions estimate for this source.

2. The 16-PAH national emissions estimate is 0.69 tons/year. The 16-PAH emission factor is 0.7233 lb/trillion Btu of heat input. These data include the following PAH: Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

B.6 INDUSTRIAL WOOD/WOOD RESIDUE COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.90E-05 lb/ton (2.95E-05 kg/Mg) and the 16-PAH emission factor was 3.36E-03 lb/ton (1.68E-03 kg/Mg). These factors were developed from the individual PAH emission factors for industrial wood waste boilers as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 90.6 million tons of oven-dried wood were burned for industrial use in the United States (EIA, 1991).

Calculation

7-PAH Annual Emissions = 5.90E-05 lb/ton * 90.6 million tons = 5,350 lb
= 2.67 tons

16-PAH Annual Emissions = 3.36E-03 lb/ton * 90.6 million tons = 3.04E+05 lb
= 152 tons

B.7 INDUSTRIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 5.56E-06 lb/MMCF (8.91E-08 g/kL). This factor was developed from the individual PAH emission factors for natural gas-fired boilers as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Acenapthylene, Fluoranthene, Naphthalene, Phenanthrene and Pyrene.

3. In 1990, 7,732 billion cubic feet of natural gas were consumed for industrial use in the United States (EIA, 1992).

Calculation

16-PAH Annual Emissions =

5.56E-06 lb/MMCF * 7,732 billion cubic feet = 43.0 lb

= 0.0215 tons

B.8 INDUSTRIAL COAL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.36E-05 lb/ton (2.68E-05 kg/Mg) and the 16-PAH emission factor was 2.72E-03 lb/ton (1.36E-03 kg/Mg). These factors was developed from the individual PAH emission factors for pulverized bituminous wet and dry-bottom and bituminous stoker industrial coal-fired boilers. An average factor was calculated using the factors from these two types of boilers (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi) Perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 115 million tons of bituminous and lignite coal and 390,000 tons of anthracite coal for a total of 115.39 million tons of coal consumed in the United States (EIA, 1992).

Calculation

7-PAH Annual Emission = 5.36E-05 lb/ton * 115.39 million tons = 6,180 lb
= 3.09 tons

16-PAH Annual Emission = 2.72E-03 lb/ton * 115.39 million tons = 3.14E+05 lb
= 157 tons

B.9 INDUSTRIAL RESIDUAL OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 1.60E-07 lb/MMBtu (6.88E-08 g/MJ) and the 16-PAH emission factor was 2.15E-04 lb/MMBtu (9.25E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 6 oil-fired industrial boiler as reported in the POM L&E document (U.S. EPA, 1996a). It was assumed that 1 gallon of residual oil produces 150,000 Btu.

2. The 7-PAH emission factor includes: Chrysene and Benzo(b)fluoranthene.

   The 16-PAH emission factor includes: Chrysene, Benzo(b)Fluoranthene, Acenapthylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, industrial residual oil consumption in the United States was 4.16E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emissions = 1.60E-07 lb/MMBtu * 4.16E+08 MMBtu	= 66.6 lb
	= 0.0333 tons
16-PAH Annual Emissions = 2.15E-04 lb/MMBtu * 4.16E+08 MMBtu	= 8.94E+04 lb
	= 44.7 tons

B.10 INDUSTRIAL WASTE OIL COMBUSTION

<u>Basis for Input Data</u>

1. The emission factor for 7-PAH was 4.53E-03 lb/1,000 gallons (5.43E-04 kg/kL) and the 16-PAH emission factor was 0.0265 lb/1,000 gallons (1.44E-03 kg/kL). These factors were developed from the individual PAH emission factors for waste oil combustion in space heaters as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor for bituminous coal includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1993, 590 million gallons of industrial waste oil was consumed in the United States (U.S. EPA, 1993a).

<u>Calculation</u>

7-PAH Annual Emission =

4.53E-03 lb/1,000 gallon * 590 million gallons	= 2,670 lb
	= 1.34 tons

16-PAH Annual Emissions =

0.0265 lb/1,000 gallons * 590 million gallons	= 1.56E+04 lb
	= 7.82 tons

B.11 INDUSTRIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.96E-09 lb/MMBtu (2.56E-09 g/MJ) and the 16-PAH emission factor was 5.00E-05 lb/MMBtu (2.15E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 2 oil-fired boiler with no control device as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor includes: Benzo(a)pyrene, Fluoranthene, Naphthalene, and Pyrene.

3. In 1990, industrial distillate oil consumption in the United States was 2.46E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

5.96E-09 lb/MMBtu * 2.46E+08 MMBtu = 1.47 lb

= 7.33E-04 tons

16-PAH Annual Emissions =

5.00E-05 lb/MMBtu * 2.46E+08 MMBtu = 1.23E+04 lb

= 6.15 tons

B.12 COMMERCIAL WOOD/WOOD RESIDUE COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 7.43E-05 lb/MMBtu (3.19E-05 g/MJ) and the 16-PAH emission factor was 2.63E-03 lb/MMBtu (1.13E-03 g/MJ). These factors were developed from the individual PAH emission factors for wood waste-fired commercial/institutional boilers as reported in the POM L&E document (U.S. EPA, 1996a). It was assumed that 1 lb of dry wood produces 8,000 Btu.

2. The 7-PAH emission factor includes Benzo(a)pyrene, Chrysene, Benz(a)anthracene, Benzo(b+k)fluoranthene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Benzo(b+k)fluoranthene, Indeno(1,2,3-cd)pyrene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, Pyrene, Acenapthylene, and Anthracene.

3. In 1994, commercial wood/wood residue consumption in the United States was 2.72E+07 MMBtu (EIA, 1991).

Calculation

7-PAH Annual Emissions = 7.43E-05 lb/MMBtu * 2.72E+07 MMBtu	= 2,020 lb
	= 1.01 tons
16-PAH Annual Emissions = 2.63E-03 lb/MMBtu * 2.72E+07 MMBtu	= 7.15E+04 lb
	= 35.8 tons

B.13 COMMERCIAL NATURAL GAS COMBUSTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data (U.S. EPA, 1996a).

   The emission factor for 16-PAH was 2.54E-05 lb/MMCF (4.07E-07 g/kL). This factor was developed from the individual PAH emission factors for natural gas fired commercial boilers reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 2,677 billion cubic feet of natural gas were consumed for commercial use in the United States (EIA, 1992).

Calculation

16-PAH Annual Emissions = 2.54E-05 lb/MMCF * 2,677 billion cubic feet = 68.0 lb
= 0.034 tons

B.14 COMMERCIAL COAL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 0.0200 lb/ton (0.0100 kg/Mg) for bituminous and lignite coal; there was no 7-PAH emission factor developed for anthracite coal combustion. The 16-PAH emission factors were 0.0771 lb/ton (0.0386 kg/Mg) for bituminous and lignite coal and 0.137 lb/ton (0.0684 kg/Mg) for anthracite coal. These factors were developed from the individual PAH emission factors for commercial coal bituminous stoker boilers as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, and Dibenz(a,h)anthracene.

   The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Benzo(ghi)perylene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 3.6 million tons of bituminous and lignite and 493,000 tons of anthracite commercial coal were consumed in the United States (EIA, 1992).

Calculation

7-PAH Annual Emissions =

0.0200 lb/ton * 3.6 million tons of bituminous and lignite coal = 7.2E+04 lb

= 36 tons

16-PAH Annual Emissions =

0.0771 lb/ton * 3.6 million tons of bituminous and lignite coal = 2.78E+05 lb

= 139 tons

16-PAH Annual Emissions =

0.137 lb/ton * 493,000 tons of anthracite coal = 6.74E+04 lb

= 33.7 tons

B.15 COMMERCIAL DISTILLATE OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 5.96E-09 lb/MMBtu (2.56E-09 g/MJ) and the 16-PAH emission factor was 5.00E-05 lb/MMBtu (2.15E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 2 oil-fired boiler with no control device as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor for bituminous coal includes: Benzo(a)pyrene, Fluoranthene, Naphthalene, and Pyrene.

3. In 1992, commercial distillate oil consumption in the United States was 5.27E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

5.96E-09 lb/MMBtu * 5.27E+08 MMBtu = 3.14 lb

= 1.57E-03 ton

16-PAH Annual Emissions =

5.00E-05 lb/MMBtu * 5.27E+08 MMBtu = 2.6E+04 lb

= 13.2 tons

B.16 COMMERCIAL RESIDUAL OIL COMBUSTION

Basis for Input Data

1. The emission factor for 7-PAH was 1.60E-07 lb/MMBtu (6.88E-08 g/MJ) and the 16-PAH emission factor was 2.14E-04 lb/MMBtu (9.20E-05 g/MJ). These factors were developed from the individual PAH emission factors for a No. 6 oil-fired industrial boiler with no control device as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benzo(b)fluoranthene and Chrysene.

   The 16-PAH emission factor includes: Benzo(b)fluoranthene, Chrysene, Acenapthylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1992, commercial residual oil consumption in the United States was 3.75E+08 MMBtu (EIA, 1992).

Calculation

7-PAH Annual Emission =

1.60E-07 lb/MMBtu * 3.75E+08 MMBtu = 60.0 lb

= 0.0300 tons

16-PAH Annual Emissions =

2.14E-04 lb/MMBtu * 3.75E+08 MMBtu = 8.025E+04 lb

= 40.1 tons

B.17 DIESEL-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - RECIPROCATING

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.36E-06 lb/MMBtu (1.44E-06 g/MJ) and the 16-PAH emission factor was 1.89E-04 lb/MMBtu (8.13E-05 g/MJ). These factors were developed from the individual PAH emission factors for industrial, commercial, and institutional engines and industrial large bore engines as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1992, distillate oil (diesel fuel) consumption in stationary reciprocating IC engines in the United States was 5.31E+07 MMBtu (EIA, 1992).

Calculation

$$\text{7-PAH Annual Emissions} = 3.36\text{E}-06 \text{ lb/MMBtu} * 5.313\text{E}+07 \text{ MMBtu} = 178 \text{ lbs} = 0.0893 \text{ tons}$$

$$\text{16-PAH Annual Emissions} = 1.89\text{E}-04 \text{ lb/MMBtu} * 5.313\text{E}+07 \text{ MMBtu} = 1.00\text{E}+04 \text{ lbs} = 5.02 \text{ tons}$$

B.18 NATURAL GAS-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - RECIPROCATING

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.75E-03 lb/MMCF (0.044 kg/MMm^3) and the 16-PAH emission factor was 0.127 lb/MMCF (2.03 kg/MMm^3). These factors were developed from the individual PAH emission factors for two-cycle lean burn and four-cycle rich burn internal combustion engines with no control devices as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1992, 750 billion cubic feet of natural gas were consumed in stationary reciprocating IC engines in the United States (EIA, 1992).

Calculation

$$\begin{aligned} \text{7-PAH Annual Emissions} &= 2.75\text{E}-03\ \text{lb/MMCF} * 750\ \text{billion cubic feet} = 2{,}060\ \text{lbs} \\ &= 1.03\ \text{tons} \end{aligned}$$

$$\begin{aligned} \text{16-PAH Annual Emissions} &= 1.27\text{E}-01\ \text{lb/MMCF} * 750\ \text{billion cubic feet} = 9.53\text{E}+04\ \text{lbs} \\ &= 47.6\ \text{tons} \end{aligned}$$

B.19 DIESEL-FIRED INTERNAL COMBUSTION ENGINES - GAS TURBINES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 1.03E-07 lb/MMBtu (4.43E-08 g/MJ). This factor was developed from the individual PAH emission factors for electric generation diesel-fired gas turbines as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Anthracene, Fluorene, and Phenanthrene.

3. In 1992, distillate oil (diesel fuel) consumption in gas turbines in the United States was 3.01E+08 MMBtu (EIA, 1992).

Calculation

$$\begin{aligned} \text{16-PAH Annual Emissions} &= 1.03\text{E}-07 \text{ lb/MMBtu} * 3.01\text{E}+08 \text{ MMBtu} = 31.0 \text{ lbs} \\ &= 0.0155 \text{ tons} \end{aligned}$$

B.20 NATURAL GAS-FIRED STATIONARY INTERNAL COMBUSTION ENGINES - GAS TURBINES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 4.90E-05 lb/MMBtu (2.11E-05 g/MJ). This factor was developed from the individual PAH emission factors for electric generation natural gas-fired gas turbines as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1992, natural gas consumption in gas turbines in the United States was 5.62E+08 MMBtu (EIA, 1992).

Calculation

$$\begin{aligned} \text{16-PAH Annual Emissions} = 4.90\text{E}{-05}\ \text{lb/MMBtu} * 5.62\text{E}{+08}\ \text{MMBtu} &= 2.75\text{E}{+04}\ \text{lb} \\ &= 13.8\ \text{ton} \end{aligned}$$

B.21 MUNICIPAL WASTE COMBUSTION

Basis for Input Data

1. There was no 7-PAH emission factor developed for this source because the emissions test data used to develop emission factors show that none of the 7-PAH were detected in any test run at any facility (U.S. EPA, 1996a; Zannes, 1996).

2. The 16-PAH emission factor is 6.07E-06 lb/ton and includes only naphthalene. The emissions test data used to develop the emission factors show that none of the other 16-PAH were detected in any test run at any facility (U.S. EPA, 1996a; Zannes, 1996).

3. In 1991, 3.24E+07 tons of municipal waste were incinerated in the United States (U.S. EPA, 1992b).

Calculation

16-PAH Annual Emissions = 6.06E-06 lb/ton * 3.24E+07 tons = 197 lb

= 0.099 tons

B.22 SEWAGE SLUDGE INCINERATION

Basis for Input Data

1. The emission factor for 7-PAH was 1.82E-05 lb/ton (9.11E-06 kg/Mg) and the 16-PAH emission factor was 3.44E-03 lb/ton (1.72E-03 kg/Mg). These factors was developed from the individual PAH emission factors for a multihearth sewage sludge incinerator with a wet scrubber as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 9.53E+05 tons of sewage sludge were incinerated in the United States (U.S. EPA, 1994a).

Calculation

7-PAH Annual Emission = 1.82E-05 lb/ton * 9.53E+05 ton = 17.4 lb
= 8.67E-03 tons

16-PAH Annual Emission = 3.44E-03 lb/ton * 9.53E+05 ton = 3.28E+03 lb
= 1.64 tons

B.23 MEDICAL WASTE INCINERATION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data (U.S. EPA, 1996a).

   The 16-PAH emission factor was 9.22E-04 lb/ton (4.61E-04 kg/Mg). This factor was developed from the individual PAH emission factors for medical waste, multi-chambered and single chambered incinerators as reported in the POM L&E document (U.S EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1990, 1.73E+06 tons of medical waste were incinerated in the United States (Copeland, 1997).

Calculation

16-PAH Annual Emission = 9.22E-04 lb/ton * 1.73E+06 tons = 1,595 lbs

= 0.798 tons

B.24 HAZARDOUS WASTE INCINERATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.91E-05 lb/ton (1.46E-05 kg/Mg) and the 16-PAH emission factor was 2.44E-04 lb/ton (1.22E-04 kg/Mg). These factors were developed from the individual PAH emission factors from a liquid injection incinerator for mixed liquid industrial waste as they are reported in the POM L&E document (U.S EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Phenanthrene, and Pyrene.

3. In 1992, approximately 249 million metric tons of hazardous waste were generated. It is estimated that of the total amount of hazardous waste incinerated, 1.3 million tons were burned in dedicated hazardous waste facilities. (Dempsey and Oppelt, 1993).

Calculation

7-PAH Annual Emission = 1.3E+06 metric tons * 1.1 ton/metric ton * 2.91E-05 lb/ton
= 42 lbs
= 0.021 tons

16-PAH Annual Emissions = 1.3E+06 metric tons * 1.1 ton/metric ton * 2.44E-04 lb/ton

= 349 lb

= 0.17 tons

B.25 DRUM AND BARREL RECLAMATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 5.53E-07 lb/1,000 barrels (2.5E-10 Mg/1,000 barrels) and the 16-PAH emission factor was 3.56E-05 lb/1,000 barrels (1.61E-08 Mg/1,000 barrels). These factors were developed from the individual PAH emission factors for 55-gallon drum recycling furnace as reported in the POM L&E document (U.S EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Chrysene, Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1994, 4.60E+06 55-gallon drums were reclaimed in the United States (U.S. EPA, 1994a).

Calculation

$$7\text{-PAH Annual Emissions} = 5.53E{-}07 \text{ lb/1,000 barrels} * 4.60E{+}06 \text{ barrels} = 2.54E{-}03 \text{ lbs}$$
$$= 1.27E{-}06 \text{ tons}$$

$$16\text{-PAH Annual Emissions} = 3.56E{-}05 \text{ lb/1,000 barrels} * 4.60E{+}06 \text{ barrels} = 0.164 \text{ lbs}$$
$$= 8.19E{-}05 \text{ tons}$$

B.26 SCRAP TIRE INCINERATION

Basis for Input Data

1. The emission factor for the 7-PAH group was 1.68E-03 lb/million tires (0.762 g/million tires) and the 16-PAH emission factor was 0.40 lb/million tires (181 g/million tires). These factors were developed from the individual PAH factors from scrap tire incinerators (U.S EPA, 1996a).

2. The 7-PAH emission factor includes Benzo(b)fluoranthene

   The 16-PAH emission factor includes Benzo(b)fluoranthene, Acenaphthene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1991, 25.9 million scrap tires were burned in the United States (U.S. EPA, 1992a).

Calculation

7-PAH Annual Emission = 1.68E-03 lb/million tires * 25.9 million tires	= 0.0435 lbs
	= 2.17E-05 tons
16-PAH Annual Emission = 0.40 lb/million tires * 25.9 million tires	= 10.4 lbs
	= 5.18E-03 tons

B.27 LANDFILL FLARES

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.08E-08 lb/MMBtu (1.32E-11 g/kJ) and the 16-PAH emission factor was 1.30E-05 lb/MMBtu (5.56E-09 g/kJ). These factors were developed from the individual PAH emission factors from a solid waste landfill waste gas flare with an afterburner control device as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1994, landfill waste gas consumed in flares in the United States was 6.85E+07 MMBtu (Berenyi, 1994).

Calculations

$$\text{7-PAH Annual Emissions} = 3.08\text{E}-08 \text{ lb/MMBtu} * 6.85\text{E}+07 \text{ MMBtu} = 2.11 \text{ lbs} = 1.05\text{E}-03 \text{ tons}$$

$$\text{16-PAH Annual Emissions} = 1.30\text{E}-05 \text{ lb/MMBtu} * 6.85\text{E}+07 \text{ MMBtu} = 890 \text{ lbs} = 0.445 \text{ tons}$$

B.28 PRIMARY ALUMINUM PRODUCTION

Basis for Input Data

1. Overall 7-PAH and 16-PAH emission factors were developed from the background information used to develop MACT standards that is presented in the Technical Support Document (U.S. EPA 1996b). Overall emission factors were developed for the individual emission factors for six processes involved in producing primary aluminum: Horizontal stud Soderberg cells; vertical Soderberg cells; pre-bake cells, casting; paste production and, anode bake furnaces (Fruh, 1997). In the reduction process, 66 percent of production is in pre-bake cells, 21 percent of production is in horizontal Soderberg cells, and 13 percent of production is in vertical Soderberg cells. The emission factors for each operation were weighted according to the respective production percent. Half of all primary aluminum produced goes through the casting process. Emission factors for paste plants and anode bake furnaces, which are given in lb/ton of paste, were converted to lb/ton aluminum by multiplying by 0.5 (typical carbon usage is 0.5 lb/lb aluminum) and were multiplied by 0.66 because only pre-bake plants have anode bake furnaces. The estimates for the individual processes for 1990 were derived based on the percent of the capacity that was uncontrolled, the percent controlled by various devices, and the appropriate emission factors for each. The overall factor is the sum of the weighted individual factors. The individual and overall factors are shown below in the calculations. The 1990 emissions estimates will be reduced by 50 percent after the primary aluminum industry MACT is implemented.

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene,Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 4.41E+06 tons of primary aluminum were produced in the United States (Plunkert and Sehnke, 1990).

Calculation

Weighted Emission Factors for Horizontal Stud Soderberg Cells
7-PAH Emission Factor = 0.058 lb/ton * 0.21 = 0.012 lb/ton
16-PAH Emission Factor = 0.59 lb/ton * 0.21 = 0.12 lb/ton

Weighted Emission Factors for Vertical Soderberg Cells
7-PAH Emission Factor = 0.12 lb/ton * 0.13 = 0.016 lb/ton
16-PAH Emission Factor = 0.49 lb/ton * 0.13 = 0.064 lb/ton

Weighted Emission Factors for Vertical Pre-bake Cells
7-PAH Emission Factor = 0.0013 lb/ton * 0.66 = 0.00086 lb/ton
16-PAH Emission Factor = 0.0073 lb/ton * 0.66 = 0.0048 lb/ton

Weighted Emission Factors for Casting Operations
7-PAH Emission Factor = 3.64E-04 lb/ton * 0.50 = 0.000182 lb/ton
16-PAH Emission Factor = 1.30E-02 lb/ton * 0.50 = 0.0069 lb/ton

Weighted Emission Factors for Paste Production

7-PAH Emission Factor = 3.7E-03 lb/ton paste * 0.5 ton paste/ton Al = 0.0019 lb/ton

16-PAH Emission Factor = 0.029 lb/ton paste * 0.5 ton paste/ton Al = 0.015 lb/ton

Weighted Emission Factors for Anode Bake Furnaces

7-PAH Emission Factor = 0.10 lb/ton anode * 0.5 ton anode/ton Al * 0.66 = 0.033 lb/ton

16-PAH Emission Factor = 0.27 lb/ton anode * 0.5 ton anode/ton Al * 0.66 = 0.089 lb/ton

Overall Emission Factors

7-PAH Emission Factor = (0.012) + (0.016) + (0.00086) + (0.000182) + (0.0019) + (0.033) = 0.064 lb/ton

16-PAH Emission Factor = (0.12) + (0.064) + (0.0048) + (0.0069) + (0.015) + (0.089) = 0.30 lb/ton

Total Annual Emissions

7-PAH Annual Emissions = 0.064 * 4.41E+06 ton	= 282,240 lbs
	= 141 tons
16-PAH Annual Emissions = 0.30 * 4.41E+06 ton	= 1,323,000 lbs
	= 662 tons

B.29 FERROALLOY MANUFACTURING

Basis for Input Data

1. The 7-PAH and 16-PAH emission factors were developed by EPA from the individual PAH emissions from open EAFs producing silicon metal, ferrosilicon, silicomanganese, ferromanganese, calcium carbide, and ferrochrome. PAH emissions from covered and semi-covered furnaces were not quantified and are assumed to be negligible because all covered and semi-covered furnaces have flares (Chin, 1997).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene for open furnaces.

   The 16-PAH emission factor includes Acenaphthene, Acenaphthylene, Benzo(b)fluoranthene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Phenanthrene, Naphthalene, and Pyrene for open furnaces.

3. Uncontrolled emission factors were developed based on fuel consumption of wood, coal, and coke (Chin, 1997).

4. The uncontrolled emission factors were converted to controlled emission factors assuming 99 percent control of organics (Chin, 1997).

5. The resulting controlled emission factors are:

<u>7-PAH</u>

0.000824 lbs/ton wood consumed
0.002324 lbs/ton coal consumed
0.000232 lbs/ton coke consumed

<u>16 PAH</u>

0.001752 lbs/ton wood consumed
0.005035 lbs/ton coal consumed
0.000503 lbs/ton coke consumed

6. The controlled emission factors were then multiplied by estimated fuel consumption for each ferroalloy manufacturing facility in the U.S. with an open furnace. Fuel consumption estimates were developed based on annual production levels (Chin, 1997).

<u>Calculation</u>

7-PAH Annual Emissions Open EAFs

0.000824 lb/ton wood consumed * 207,513 tons wood = 170.99 lbs
0.002324 lb/ton coal consumed * 141,836 tons coal = 316.63 lbs.
0.000232 lb/ton coke consumed * 89,390 tons coke = 20.74 lbs.

16 PAH Annual Emissions Covered and Semi-covered EAFs

0.001752 lb/ton wood consumed * 207,513 tons wood = 363.56 lbs

0.005035 lb/ton coal consumed * 141,836 tons coal = 714.14 lbs

0.000503 lb/ton coke consumed * 89,390 tons coke = 44.96 lbs

<u>Total Annual Emission</u>

7-PAH = 170.99 lbs + 316.63 lbs + 20.74 lbs ÷ 2000 = 0.25 tons

16-PAH = 363.56 lbs + 714.14 lbs + 44.96 lbs ÷ 2000 = 0.56 tons

B.30 IRON AND STEEL FOUNDRIES

<u>Basis for Input Data</u>

1. The emission factor for 7-PAH was 2.07E-05 lb/ton (1.04E-05 kg/Mg) and 16-PAH emission factor was 5.82E-03 lb/ton (2.91E-03 kg/Mg). These factors were developed from the individual PAH emission factors for two types of iron and steel foundries, cupola furnaces and green sand casting operation as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 10.2 million tons of iron and steel were produced in the United States (U.S. Department of Interior, 1991).

<u>Calculation</u>

7-PAH Annual Emission = 2.07E-05 lb/ton * 10.2 million tons = 211 lb
= 0.106 tons

16-PAH Annual Emission = 5.82E-03 lb/ton * 10.2 million tons = 5.94E+04 lb
= 29.7 tons

B.31 SECONDARY LEAD SMELTING

Basis for Input Data

1. The calculation of national emissions for the secondary lead category was based on the most recent emission factor test data for POM species that could be determined and the production levels of lead by furnace type. Much of the information for these estimates was obtained from the EPA staff involved with the development of the MACT standard for this source category. Production data were provided by the MACT staff for three breakdowns of furnace type. These are as follows.

Blast Furnaces:	273,396 Mg/yr production
Blast/Reverb Furnaces:	613,902 Mg/yr production
Reverb and Rotary Furnaces:	305,176 Mg/yr production
TOTAL:	1,192,474 Mg/yr

   POM emission factors were not available for each of these furnace types; therefore, assumptions had to be made that resulted in combining some furnace types together in order to calculate emissions. Based on input from the MACT team, the production data for the Blast/Reverb and the Reverb and Rotary were combined together and applied to the emission factors that were available for rotary furnaces. The production breakdowns, by furnace type, that were used to calculate national emissions are as follows.

Blast Furnaces:	273,396 Mg/yr
Blast/Reverb and Rotary Furnaces:	919,078 Mg/yr
TOTAL:	1,192,474 Mg/yr

2. The emission factors were determined for each of the POM classes (7-PAH and 16-PAH) by furnace grouping. Each grouping is explained below.

Blast Furnaces

a. 7-PAH Factor: The available test data had no results for any of the species identified as being in the 7-PAH group,; therefore, there is no 7-PAH factor for blast furnaces. Consequently, there is no national emission estimate for this source as well.

b. 16-PAH Factor: The only POM specie for which test data were reported is naphthalene. Two factors were available, one from an uncontrolled source and one from a controlled source. Based on input from the MACT development team on the control status of all facilities once the MACT rule becomes effective, the decision was made to reflect a controlled situation for the purposes of the national emissions estimate. Taking this approach better mirrors the current and future configuration of the industry.

The two naphthalene emission factors are:

- 0.182 lb/ton (0.0911 kg/Mg), Uncontrolled
- 0.0125 lb/ton (0.00626 kg/Mg), Controlled

To determine blast furnace emissions, a composite emission factor was calculated using these two values. The uncontrolled factor was modified to reflect a controlled status by applying the control efficiency of 85 percent expected by the MACT rule for blast furnaces. The calculation is:

(0.182 lb/ton) x (0.15) = 0.0273 lb/ton (0.0137 kg/Mg)

This factor was averaged with the controlled test data factor of 0.0125 lb/ton (0.00626 kg/Mg) to determine the composite blast furnace factor.

(0.0273 lb/ton) + (0.0125 lb/ton)/2 = 0.0199 lb/ton (0.0100 kg/Mg)

The composite (controlled) emission factor = 0.0199 lb/ton (0.0100 kg/Mg)

Rotary and Blast/Reverb Furnaces

a. 7-PAH Factor: The available test data from the MACT program only contained data for one specie in the list of 7-PAH. This specie was chrysene. The uncontrolled chrysene emission factor that was developed from the data was:

0.00183 lb/ton (0.000917 kg/Mg), Uncontrolled

The same rationale and approach described above in terms of reflecting controlled MACT levels for national emissions was applied here as well. The MACT team indicated that for these sources a control of approximately 98 percent would be achieved. The uncontrolled chrysene factor was adjusted accordingly as follows.

(0.00183 lb/ton) x (0.02) = 0.000037 lb/ton (0.000018 kg/Mg)

This factor was used to calculate national emissions.

B. 16-PAH Factor: There are only two species available from the test data to constitute the 16-PAH factor. These are the chrysene data shown above and data reported for pyrene. The 16-PAH factor used for national estimate calculations represents the sum of these two data points. The pyrene data (uncontrolled) were manipulated as follows to determine the value for national estimate calculation purposes.

(0.000722 lb/ton) x 0.02 = 0.000014 lb/ton (0.000007 kg/Mg)

The controlled factor = 0.000014 lb/ton (0.000007 kg/Mg)

The 16-PAH factor = 0.000014 lb/ton + 0.000037 lb/ton = 0.000051 lb/ton (0.000026 kg/Mg)

More details and specific references on the source test data from the MACT development program used to develop these national estimate emission factors can be found in the 1996 POM Locating and Estimating Document issued by EPA (U.S. EPA, 1996a).

Calculation

1. 7-PAH Emissions:

Blast Furnaces

As discussed above, due to a lack of data, there is no national estimate for blast furnaces for the 7-PAH group.

B.31 SECONDARY LEAD SMELTING (Continued)

Rotary and Blast/Reverb

(919,078 Mg/yr production) x (0.000018 kg/Mg) = 0.017 Mg/yr (represents only chrysene)

2. 16-PAH Emissions:

Blast Furnaces

(273,396 Mg/yr production) x (0.0100 kg/Mg) = 2.734 Mg/yr (represents only naphthalene)

Rotary and Blast/Reverb

(919,078 Mg/yr production) x (0.000026 kg/Mg) = 0.024 Mg/yr (represents chrysene and pyrene)

EMISSIONS SUMMARY

Furnace Type	7-PAH Emissions (Mg/yr)	16-PAH Emissions (Mg/yr)
Blast	No Data	2.734
Rotary and Blast/Reverb	0.017	0.024
TOTAL	0.017	2.758

B.32 PETROLEUM REFINERY CATALYTIC CRACKING UNITS

Basis for Input Data

1. The emission factor for the 7-PAH group was 1.66E-05 lb/barrel (7.53E-06 kg/barrel) and the 16-PAH emission factor was 3.16E-04 lb/barrel (1.43E-04 kg/barrel). These factors were developed from the individual PAH emission factors for two types of catalytic cracking units (U.S. EPA, 1996a). Fluid catalytic cracking units make up 90 percent of the cracking units. Moving-bed catalytic cracking units make up the remaining 10 percent. The emission factors were developed using a weighted average based on the percentage each type of cracking unit contributes to the total production.

2. The 7-PAH emission factor includes: Benzo(a)pyrene.

   The 16-PAH emission factor includes: Benzo(a)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1991, 1.98E+09 barrels of oil were charged to catalytic cracking units in the United States (Oil and Gas Journal, 1991).

Calculation

$$\begin{aligned}\text{7-PAH Annual Emissions} = 1.66\text{E}{-05}\ \text{lb/barrel} * 1.98\text{E}{+09}\ \text{barrels} &= 3.29\text{E}{+04}\ \text{lbs}\\ &= 16.4\ \text{tons}\end{aligned}$$

$$\begin{aligned}\text{16-PAH Annual Emissions} = 3.16\text{E}{-04}\ \text{lb/barrel} * 1.98\text{E}{+09}\ \text{barrels} &= 6.26\text{E}{+05}\ \text{lbs}\\ &= 313\ \text{tons}\end{aligned}$$

B.33 ASPHALT ROOFING MANUFACTURING

Basis for Input Data

1. The emission factor for the 7-PAH group was 1.10E-04 lb/ton (5.50E-05 kg/Mg) for felt saturation. There is no 7-PAH emission factor for asphalt blowing because none of the 7-PAH were reported in the available test data. The 16-PAH emission factors were 5.10E-03 lb/ton (2.55E-03 kg/Mg) for asphalt blowing and 3.17E-04 lb/ton (1.58E-04 kg/Mg) for felt saturation. The overall 7-PAH emission factor was 1.10E-04 lb/ton (5.50E-05 kg/Mg) and the overall 16-PAH emission factor was 2.86E-03 lb/ton (1.93E-03 kg/Mg) (U.S. EPA, 1980b).

   These factors were developed from the individual PAH emission factors for two processes involved in producing asphalt roofing: asphalt blowing and felt saturation. Half of the weight of asphalt roofing products is blown asphalt. The overall emission factors were calculated by summing the total emissions from asphalt blowing and felt saturation and dividing by the total asphalt roofing produced.

2. The 7-PAH emission factor includes: Benz(a)anthracene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Chrysene, Anthracene, Fluoranthene, and Phenanthrene.

3. In 1993, 3.05E+07 tons of asphalt roofing was produced in the United States (Asphalt Roofing Manufacturers Association, 1994).

Calculation

Asphalt Blowing

16-PAH Annual Emissions = 5.10E-03 lb/ton * 1.52E+07 tons	= 7.75E+04 lb
	= 38.8 tons

Felt Saturation

7-PAH Annual Emissions = 1.1E-04 lb/ton * 3.05E+07 tons	= 3360 lb
	= 1.68 tons
16-PAH Annual Emissions = 3.17E-04 lb/ton * 3.05E+07 tons	= 9,670 lb
	= 4.83 tons

Total Emissions

7-PAH Total Annual Emission 1.68 tons + 0 tons	= 1.68 tons
16-PAH Total Annual Emission 4.83 + 38.8 tons	= 43.6 tons

B.34 ASPHALT HOT-MIX PRODUCTION

Basis for Input Data

1. The emission factor for the 7-PAH group was 3.90E-07 lb/ton (1.95E-07 kg/Mg) and the 16-PAH emission factor was 1.82E-04 lb/ton (9.10E-05 kg/Mg). These factors were developed from the individual PAH emission factors for natural gas- or propane-fired dryers, oil-fired dryers, natural gas-fired dryer with fabric filter and oil-fired dryer with fabric filter as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1993, 4.80E+08 tons of hot-mix asphalt were produced in the United States (NAPA, 1993).

Calculation

$$\begin{aligned} 7\text{-PAH Annual Emissions} &= 3.90\text{E}{-07}\ \text{lb/ton} * 4.80\text{E}{+08}\ \text{tons} = 187\ \text{lbs} \\ &= 0.094\ \text{tons} \end{aligned}$$

$$\begin{aligned} 16\text{-PAH Annual Emissions} &= 1.82\text{E}{-04}\ \text{lb/ton} * 4.80\text{E}{+08}\ \text{tons} = 8.74\text{E}{+04}\ \text{lbs} \\ &= 43.7\ \text{tons} \end{aligned}$$

B.35 COKE OVENS: CHARGING, DOOR, AND TOPSIDE LEAKS

Basis for Input Data

1. The emission factor for the 7-PAH group is 1.1E-03 lb/ton (5.5E-04 kg/Mg) and the 16-PAH emission factor is 8.2E-03 lb/ton (4.1E-03 kg/Mg). These factors were developed from the individual PAH emission factors for controlled oven charging, oven door, lid leaks, and offtake leaks as reported in EPA's AP-42 document (U.S. EPA, 1996c).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, 3.86E+07 tons of coal were charged to coke ovens in the United States (EIA, 1990).

B.35 COKE OVENS: CHARGING, DOOR, AND TOPSIDE LEAKS (Continued)

Calculation

7-PAH Annual Emissions = 1.1E-03 lb/ton * 3.86E+07 tons = 4.25E+04 lbs
= 21.2 tons

16-PAH Annual Emissions = 8.2E-03 lb/ton * 3.86E+07 tons = 3.17E+05 lbs
= 158 tons

B.36 COKE OVENS: PUSHING, QUENCHING, AND BATTERY STACKS

Basis for Input Data

1. The emission factors for the 7-PAH group and the 16-PAH group were derived from data reported in the U.S. Environmental Protection Agency Locating and Estimating Document for POM (U.S. EPA, 1996a). The factors used in the 112(c)(6) analysis were developed from the individual PAH emission factors for uncontrolled oven pushing, oven underfiring, and quenching. The individual PAH data were obtained from various source test reports for these sources. Most all of the data dated back to the 1980's and late 1970's.

2. Because of the scarcity of data for these sources types, the available factors were combined together and reported as one factor applicable to the group of sources as a whole. The factors used to estimate emissions for pushing, quenching, and battery stacks are:

   7-PAH: 3.093E-03 lb/ton (1.55E-03kg/Mg) of coal charged
   16-PAH: 0.053 lb/ton (0.026 kg/Mg) of coal charged

   These factors were multiplied by the national activity data for 1990 to obtain national uncontrolled emissions.

3. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Diben(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene,

B.36 COKE OVENS: PUSHING, QUENCHING, AND BATTERY STACKS (Continued)

Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

4. The uncontrolled emission rate was adjusted for controls in place by using an overall control efficiency derived from available data. The control efficiency figure was derived by averaging data from Trenholm and Beck, 1978 and EPA's AP-42 document. The AP-42 data were obtained from the May, 1995 draft section on coke ovens which EPA felt was the most recent and reliable data available. Control efficiencies for these operations were back calculated from the uncontrolled and controlled emission factors reported in AP-42. Based on the engineering judgements of EPA specialists on coke ovens, a conservative control efficiency value was averaged from the AP-42 data to reflect the fact that the entire category is not well controlled for these sources. The average control efficiency value for these source types that was derived and used for this analysis is 49.5 percent control.

5. In 1990, 3.86E+07 tons of coal were charged to coke ovens in the United States (EIA, 1990).

Calculation

A. 7-PAH National Emissions (Uncontrolled)

=0.00309 lb/ton * 3.86E+07 tons/yr = 119,274 lb
= 59.6 tons/yr

7-PAH National Emissions (Controlled)

=59.6 tons/yr * (1-0.495) = 30.1 tons/yr

B.36 COKE OVENS: PUSHING, QUENCHING, AND BATTERY STACKS (Continued)

B. 16-PAH National Emissions (Uncontrolled)

=0.053 lb/ton * 3.86E+07 tons/yr = 2,045,800 lbs

= 1,022.9 tons/yr

16-PAH National Emissions (Controlled)

= 1,022.9 tons/yr * (1-0.495) = 516.6 tons/yr

B.37 PORTLAND CEMENT MANUFACTURING

Basis for Input Data

1. The emission factors used to estimate annual emissions for hazardous waste (HW) kilns and non-hazardous (NHW) waste kilns were developed from data presented in the POM Locating and Estimating document (U.S. EPA 1996a). These data include emissions of individual PAHs from HW and NHW kilns. The individual emissions were summed to develop 7-PAH and 16-PAH emission factors and all factors for HW kilns were averaged to produce overall averages for HW kilns. The same procedure was used for NHW kilns.

2. The activity data used to estimate annual emissions from HW and NHW kilns were obtained from memorandums written by Elizabeth Heath, Research Triangle Institute to Joseph Wood, U.S. EPA (Heath, 1996a), (Heath, 1996b). These memorandums presented national baseline emission calculations for dioxins/furan from HW and NHW kilns. A value of 67.6 million tons of clinker per year was used to calculate emissions from HW kilns, and a value of 36,630,691 was used for NHW kilns.

Non-Hazardous Waste Kilns

1. The emission factor for the 7-PAH group was 8.21E-05 lb/ton (4.11E-05 kg/Mg) and the 16-PAH emission factor was 1.51E-03 lb/ton (7.55E-04 kg/Mg). These factors were developed from the individual PAH emission factors for a coal-fired precalciner dry process kiln, a coal-fired wet process kiln, a coal/coke-fired wet process kiln, and a coal/TDF-fired wet process kiln.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. Calculations

7-PAH annual emissions = 8.21E-05 lb/ton * 67.6E+06 tons = 5,553 lbs = 2.78 tons
16-PAH annual emissions = 1.51E-03 lb/ton * 67.6E+06 tons = 102,027 lbs = 51 tons

Hazardous Waste Kilns

1. The emission factor for the 7-PAH group was 2.52E-04 lb/ton (1.26E-04 kg/Mg) and the 16-PAH emission factor was 1.53E-03 lb/ton (7.65E-04 kg/Mg). These factors were developed from the individual PAH emission factors for two coal/coke/hazardous waste-fired wet process kilns, a coal/hazardous waste-fired wet process kiln, a hazardous waste-fired wet process kiln, a gas/hazardous waste-fired wet process kiln, a coal/coke/hazardous waste-fired dry process kiln, and a coal/hazardous waste-fired dry process kiln.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. Calculations

7-PAH annual emissions = 2.52E-04 lb/ton *36,630,691 tons = 9,217 lbs = 4.61 tons

16-PAH annual emissions = 1.53E-03 lb/ton * 36,630,691 tons = 56,045 lbs = 28 tons

B.38 PULP AND PAPER--KRAFT RECOVERY FURNACES

Basis for Input Data

1. Two general types of furnaces are used for this process, direct contact evaporators (DCE) and non-direct contact evaporators (NDCE). POM emission factor data were available from industry reports for both types of units; however, activity data were not found on a process-specific basis. Activity data were only found as a total for all furnaces. 7-PAH and 16-PAH national emission estimates were calculated by determining an average emission factor across all furnace types and applying this factor to total furnace activity. The emission factor data used in the analysis and the PAH compounds represented in the estimate are shown below (NCASI, 1993).

PAH Specie	7- or 16-PAH	NDCE/ Dry Bottom ESP[a]	NDCE/ Wet Bottom ESP/Scrubber[a]	DCE/ Wet Bottom ESP/Scrubber[a]
Benz(a)anthracene	7-PAH, 16-PAH	1.20E-05	3.50E-06	9.60E-05
Benz(o)pyrene	7-PAH, 16-PAH	2.60E-06	3.50E-06	5.80E-06
Benzo(b)fluoranthene	7-PAH, 16-PAH	6.40E-06	3.50E-06	2.90E-05
Benzo(k)fluoranthene	7-PAH, 16-PAH		3.50E-06	8.00E-06
Chrysene	7-PAH, 16-PAH	6.50E-05	3.50E-06	3.90E-05
Dibenz(a,h)anthracene	7-PAH, 16-PAH	6.00E-06	3.50E-06	6.80E-06
Indeno(1,2,3-cd)pyrene	7-PAH, 16-PAH	6.00E-06	3.50E-06	4.20E-06
Acenaphthene	16-PAH	5.00E-06	3.50E-06	1.60E-05
Acenaphthylene	16-PAH		1.30E-05	2.60E-03
Anthracene	16-PAH		3.50E-06	4.00E-04
Benzo(ghi)perylene	16-PAH	7.90E-06	3.50E-06	1.20E-05
Fluoranthene	16-PAH		1.90E-05	6.90E-04
Fluorene	16-PAH		3.50E-06	2.10E-04
Naphthalene	16-PAH		6.40E-04	3.20E-02
Phenanthrene	16-PAH		9.50E-06	5.60E-03

B.38 PULP AND PAPER--KRAFT RECOVERY FURNACES (Continued)

Pyrene	16-PAH	1.00E-04	1.10E-05	3.30E-04
SUM of 7-PAH EF[b]		8.80E-05	2.45E-05	1.89E-04
SUM of 16-PAH EF[c]		2.01E-04	8.17E-04	4.20E-02
NCDE Average EF				
7-PAH EF	5.63E-05			
16-PAH EF	5.09E-04			
DCE EF				
7-PAH EF	1.89E-04			
16-PAH EF	4.20E-02			
Overall Average EF[d]				
7-PAH EF	1.23E-04			
16-PAH EF	2.13E-02			

[a]All emission factor data are in units of lb emissions/ton air dried pulp.
[b]This row represents the sum of 7-PAH emission factors.
[c]This row represents the sum of 16-PAH emission factors.
[d]Overall average of the NDCE and DCE average emission factors.
NDCE = Non-direct Contact Evaporator
DCE = Direct Contact Evaporator

2. The individual emission factor data for 7- and 16-PAH were totaled to produce a sum of 7-PAH and a sum of 16-PAH emission factor. The two sets NCDE factors were then averaged together to produce an average factor for NCDE units. The NCDE average factor was then averaged together with the DCE factor to produce the overall factor used to calculate a national emissions estimate.

3. The overall average emission factors were applied to an annual activity level for recovery furnaces of 6.10E+07 tons of air-dried pulp in the United States (U.S. EPA, 1993).

B.38 PULP AND PAPER--KRAFT RECOVERY FURNACES (Continued)

<u>Calculation</u>

7-PAH Annual Emission = 1.89E-04 lb/ton pulp * 6.10E+07 tons pulp =
7,474 pounds = 3.74 tons/yr

16-PAH Annual Emission = 4.20E-02 lb/ton pulp * 6.10E+07 tons pulp =
1,297,943 pounds = 649 tons/yr

B.39 PULP AND PAPER--LIME KILNS

Basis for Input Data

1. The emission factor for 7-PAH was 3.30E-06 lb/MMBtu (1.42E-06 g/MJ) and the 16-PAH emission factor was 2.46E-03 lb/MMBtu (1.06E-03 g/MJ). These factors was developed from the individual PAH emission factors for two natural gas-fired lime kilns. Both kilns were controlled with scrubbers as reported in the POM L&E document (U.S. EPA, 1996a). It was assumed that there are 550 CaO per ton pulp, 8 MMBtu per ton lime product, and 90 percent lime availability, i.e., 0.9 ton CaO per ton lime product.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Anthracene, Fluoranthene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1990, the energy consumed in pulp and paper lime kilns in the United States was 1.49E+08 MMBtu (U.S. EPA, 1993).

Calculation

7-PAH Annual Emission = 3.30E-06 lb/MMBtu * 1.49E+08 MMBtu = 492 lb
= 0.246 tons

16-PAH Annual Emission = 2.46E-03 lb/MMBtu * 1.49E+08 MMBtu = 3.67E+05 lb
= 183 tons

B.40 SULFITE RECOVERY FURNACES

<u>Basis for Input Data</u>

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH's were reported in the available test data.

   The 16-PAH emission factor was 4.30E-03 lb/ADTP (2.15E-03 kg/Mg). This factor was developed from the individual PAH emission factors for ammonia-based sulfite recovery furnace as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 2.87E+06 tons of pulp were produced in the United States (U.S. EPA, 1993).

<u>Calculation</u>

16-PAH Annual Emission = 4.30E-03 lb/ADTP * 2.87E+06 tons = 1.23E+04 lb
= 6.17 tons

B.41 WILDFIRES AND PRESCRIBED BURNING

Basis for Input Data

1. The emission factor for the 7-PAH group was 0.020 lb/ton (0.010 kg/Mg) and the 16-PAH emission factor was 0.053 lb/ton (0.027 kg/Mg). These factors were developed from the individual PAH emission factors for wildfire and prescribed burning of pine needles, agricultural fields temperate and bared forest and sugar cane as they are reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 9.50E+07 tons of biomass were burned in the United States (Peterson and Ward, 1993; U.S. Forest Service, 1993).

Calculations

7-PAH Annual Emissions 0.020 lb/ton * 9.50E+07 tons = 1.93E+06 lbs
= 964 tons

16-PAH Annual Emissions 0.053 lb/ton * 9.50E+07 tons = 5.07E+06 lbs
= 2,540 tons

B.42 OPEN BURNING OF SCRAP TIRES

Basis for Input Data

1. The emission factor for the 7-PAH was 1,400 lb/1,000 tons of tire (0.70 kg/Mg) and the 16-PAH emission factor was 7,850 lb/1,000 tons of tire (3.93 kg/Mg). These factors were developed from the individual PAH emission factors from simulation of open burning of chunk and shredded scrap tires as they are reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Acenapthylene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1993, 4.38E+05 tons of tires were burned in the United States (Lemieux and Ryan, 1993).

Calculation

7-PAH Annual Emissions = 1,400 lb/1,000 tons * 4.38E+05 tons = 6.13E+05 lbs

= 307 tons

16-PAH Annual Emissions = 7,850 lb/1,000 tons * 4.38E+05 tons = 3.44E+06 lbs

= 1,720 tons

B.43 MOBILE SOURCES--ONROAD VEHICLES

Basis for Input Data

1. The emission factors for 7-PAH and the 16-PAH emission factors are provided in Table A-22a (of Appendix A). These factors were developed from the individual PAH emission factors for specific vehicle types. Fleet-wide emission factors were developed taking into consideration areas with and without inspection and maintenance programs.

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, and Indeno(1,2,3-cd)pyrene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Indeno(1,2,3-cd)pyrene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 2,147 billion vehicle miles were traveled in the United States (U.S. Department of Transportation, 1990).

Calculation

7-PAH Annual Emission = 7.95 μg/mile * 2,147 billion miles = 17.069 Mg
= 18.81 tons

16-PAH Annual Emission = 19.704 μg/mile * 2,147 billion miles = 42.304 Mg
= 46.63 tons

B.44 MOBILE SOURCES--AIRCRAFT

Basis for Input Data

1. The emission factor for 7-PAH was 1.09E-05 lb/landing and takeoff cycle (LTO) (4.94E-09 Mg/LTO) and the 16-PAH emission factor was 3.06E-04 lb/LTO (1.39E-07 Mg/LTO). These factors was developed from the individual PAH emission factors for an aircraft gas turbine engine as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Anthracene, Benzo(ghi)perylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1990, 1.22E+07 LTO's in the United States (FAA, 1990).

Calculation

7-PAH Annual Emission = 1.09E-05 lb/LTO * 1.22E+07 LTO's = 133 lb
= 0.0665 tons

16-PAH Annual Emission = 3.06E-04 lb/LTO * 1.22E+07 LTO's = 3,730 lb
= 1.87 tons

B.45 CARBON BLACK MANUFACTURING

Basis for Input Data

1. The emission factor for the 7-PAH group was 5.25E-04 lb/ton (2.63E-04 kg/Mg) and the 16-PAH emission factor was 5.04E-03 lb/ton (2.52E-03 kg/Mg). These factors were developed from the individual PAH emission factors for oil furnace carbon black manufacturing as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Chrysene.

   The 16-PAH emission factors include: Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Acenapthylene, Fluoranthene, Phenanthrene, and Pyrene.

3. In 1993, the industry had a capacity to produce 1.72E+06 tons of carbon black in the United States (SRI, 1993).

Calculations

$$\begin{aligned}\text{7-PAH Annual Emissions} = 5.25\text{E}-04 \text{ lb/ton} * 1.72\text{E}+06 \text{ tons} &= 903 \text{ lbs}\\ &= 0.451 \text{ tons}\end{aligned}$$

$$\begin{aligned}\text{16-PAH Annual Emissions} = 5.04\text{E}-03 \text{ lb/ton} * 1.72\text{E}+06 \text{ tons} &= 8{,}670 \text{ lbs}\\ &= 4.33 \text{ tons}\end{aligned}$$

B.46 WOOD TREATMENT/WOOD PRESERVING WITH CREOSOTE

Basis for Input Data

1. There is no 7-PAH emission factor for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 1.94E-03 lb/ft^3 (0.0311 kg/m^3). This factor was developed from the individual PAH emission factors from creosote wood treatment process and diluent wood treated as reported in the POM L&E document (U.S. EPA, 1996a). (Does not include fugitives from treated wood storage.)

2. The 16-PAH emission factor includes: Acenaphthene, Fluorene, Naphthalene, and Phenanthrene.

3. In 1993, 4.71E+08 ft^3 of wood were treated with creosote in the United States (Micklewright, 1994).

Calculations

$$\begin{aligned} \text{16-PAH Annual Emissions} &= 1.94\text{E}-03 \text{ lb/ft}^3 * 4.71\text{E}+08 \text{ ft}^3 = 9.14\text{E}+05 \text{ lbs} \\ &= 457 \text{ tons} \end{aligned}$$

B.47 CIGARETTE SMOKE

Basis for Input Data

1. The emission factor for the 7-PAH group was 2.08E-09 lb/cigarette (9.43E-10 kg/cigarette) and the 16-PAH emission factor was 1.38E-08 lb/cigarette (6.26E-09 kg/cigarette). These factors were developed from the individual PAH emission factors from cigarette as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH emission factor includes: Benz(a)anthracene and Chrysene

   The 16-PAH emission factor includes: Benz(a)anthracene, Chrysene, Anthracene, Fluoranthene, Phenanthrene and Pyrene.

3. In 1992, 5.00E+11 cigarettes were consumed in the United States (USDA, 1993).

Calculation

7-PAH Annual Emissions = 2.08E-09 lb/cigarette * 5.00E+11 cigarettes = 1,040 lbs
= 0.520 tons

16-PAH Annual Emissions = 1.38E-08 lb/cigarette * 5.00E+11 cigarettes = 6,900 lbs
= 3.45 tons

B.48 CREMATORIES

<u>Basis for Input Data</u>

1. The emission factor for the 7-PAH group was 7.07E-11 lb/body (3.21E-11 kg/body) and the 16-PAH emission factor was 4.16E-08 lb/body (1.89E-08 kg/body). These factors were developed from the individual PAH emission factors from crematory stacks as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 7-PAH Emissions factor includes: Benz(a)anthracene, Benzo(a)pyrene and Chrysene.

   The 16-PAH emission factor includes: Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Acenaphthene, Acenapthylene, Anthracene, Fluoranthene, Fluorene, Naphthalene, Phenanthrene, and Pyrene.

3. In 1992, 4.00E+05 cremations were performed in the United States (Cremation Association of North America, 1992).

<u>Calculation</u>

7-PAH Annual Emissions = 7.07E-11 lb/body * 4.00E+05 bodies = 2.83E-05 lbs
= 1.42E-08 tons

16-PAH Annual Emissions = 4.16E-08 lb/body * 4.00E+05 bodies = 0.0166 lbs
= 8.33E-06 tons

B.49 GASOLINE DISTRIBUTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source category because none of the 7-PAH were reported in the available test data.

   The 16-PAH emissions for this source category only include naphthalene. A single 16-PAH emission factor could not be developed for this source category because the nature of a significant amount of the national emissions do not lend themselves to establishing emission factors of the type developed for other POM categories.

2. Instead of developing an overall emission factor, national emissions were calculated as follows.

   To develop the Gasoline Distribution (Stage I) NESHAP (U.S. EPA, 1994b; U.S. EPA, 1994c), national annual VOC and HAP emissions from the source category were estimated for the base year 1998; emission estimates for 1990 were not provided. For the purposes of this report, 1990 emissions were estimated by scaling down the 1998 emissions estimates in the NESHAP using the ratio of the projected 1998 gasoline consumption (117.9 billion gallons) to the Department of Energy's record of 1990 gasoline consumption (110.5 billion gallons). This approach reduces the 1998 base year emissions by 6.28 percent. Adjustments made in the NESHAP for the level of control projected in 1998 and anticipated future uses of alternative fuels could not be taken into consideration when 1998 emissions were adjusted to 1990 in this survey, so the emissions estimates made here may slightly underestimate the actual 1990 emissions.

As stated previously, national annual VOC and HAP emissions were estimated for different processes throughout the Stage I gasoline distribution network taking into account the projected control programs in each State (LaFlam and Johnson, 1996). According to the documentation for the Gasoline Distribution NESHAP, naphthalene is 0.80 percent of total HAP emissions. Taking this into consideration, national annual naphthalene Stage I emissions are 376 tons for 1998. This estimate was adjusted to reflect emissions in 1990, yielding a national annual naphthalene estimate of 352 tons.

3. The estimating method for emissions from Stage II gasoline distribution sources was taken from the approach for vehicle refueling outlined in the EPA's Technical Guidance - Stage II document (U.S. EPA, 1991). A VOC emission factor was obtained from MOBILE 4.1, EPA's mobile source emission factor computer model. The VOC emission factors relative to monthly temperatures nationwide were applied to gasoline throughput to estimate emissions. Naphthalene emissions were estimated using the speciation value of 0.05 percent naphthalene in total VOC provided in the documentation for the Gasoline Distribution NESHAP (LaFlam and Johnson, 1996; U.S. EPA, 1994c).

The above emissions estimate approach is conservative because it was assumed that all fuel throughput is via conventional refueling methods and it does not take into consideration any Stage II emission controls. However, the emission factors used in the Stage II document do not include spillage losses.

B.49 GASOLINE DISTRIBUTION (Continued)

Calculation

Stage I emissions:

National emissions estimate for Stage I	=	1998 naphthalene emissions estimate (tons/yr) from NESHAP x (100 - percent reduction fuel consumption, 1998 to 1990)
	=	342 Mg x 1.102 tons/Mg x (100 - 6.28) percent
	=	353 tons/yr

Stage II emissions:

National emissions estimate for Stage II	=	VOC emission factor (lb/gal) x gasoline throughput (gal/yr) x naphthalene content
	=	$0.013601 \times 1.11 \times 10^{11} \times 0.0005$
	=	374 tons/yr

Total national emissions estimate for gasoline distribution

	=	353 + 374
	=	727 tons/yr

B.50 NAPHTHALENE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available data.

   The 16-PAH emission factors were 0.523 lb/ton (0.262 kg/Mg) of naphthalene produced and 0.0024 lb/ton (0.0012 kg/Mg) of coke produced. These factors were developed from the individual PAH emission factors from the coal tar distillation process and coke by-product recovery plants as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes Naphthalene.

3. In 1993, 1.23E+05 tons of naphthalene and 2.70E+07 tons of coke were produced in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

Naphthalene Production

16-PAH Annual Emissions = 0.523 lb/ton * 1.23E+05 tons	= 6.41E+04 lbs
	= 32.2 tons

Coke Production

16-PAH Annual Emissions = 0.0024 lb/ton * 2.70E+07 tons	= 6.48+04 lbs
	= 32.4 tons

Total Annual Emissions = 32.2 tons + 32.4 tons	= 64.6 tons

B.51 NAPHTHALENE USE - PHTHALIC ANHYDRIDE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene processed. This factor was developed from individual PAH emission factors for storage and transfer of naphthalene used in the production of phthalic anhydride (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 1.54E+08 lbs of naphthalene were consumed to produce phthalic anhydride in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$\begin{aligned} 16\text{-PAH Annual Emissions} = 0.034 \text{ lb/100 lbs} * 1.54\text{E+08 lbs} &= 5.24\text{E+04 lbs} \\ &= 26.2 \text{ tons} \end{aligned}$$

B.52 NAPHTHALENE USE - CARBAMATE INSECTICIDE PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for carbamate insecticide production as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 2.40E+07 lbs of naphthalene were consumed to produce carbamate insecticides in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$\begin{aligned} 16\text{-PAH Annual Emissions} &= 0.034 \text{ lb/100 lbs} * 2.40\text{E}{+}07 \text{ lbs} = 8.16\text{E}{+}03 \text{ lbs} \\ &= 4.08 \text{ tons} \end{aligned}$$

B.53 NAPHTHALENE USE - NAPHTHALENE SULFONATES PRODUCTION

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for naphthalene sulfonate production as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 3.84E+07 lbs of naphthalene were consumed to produce naphthalene sulfonates in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$\begin{aligned}16\text{-PAH Annual Emissions} &= 0.034 \text{ lb/100 lbs} * 3.84\text{E}{+}07 \text{ lbs} = 1.31\text{E}{+}04 \text{ lbs}\\ &= 6.53 \text{ tons}\end{aligned}$$

B.54 NAPHTHALENE - MISCELLANEOUS USES

Basis for Input Data

1. There is no 7-PAH emission factor developed for this source because none of the 7-PAH were reported in the available test data.

   The 16-PAH emission factor was 0.34 lb/1000 lbs (0.34 kg/Mg) naphthalene consumed. This factor was developed from the individual PAH emission factors for miscellaneous uses of naphthalene as reported in the POM L&E document (U.S. EPA, 1996a).

2. The 16-PAH emission factor includes: Naphthalene.

3. In 1993, 7.20E+06 lbs of naphthalene were consumed in miscellaneous uses in the United States (Mannsville Chemical Products Corporation, 1993).

Calculation

$$\begin{aligned} 16-\text{PAH Annual Emissions} = 0.034 \text{ lb/100 lbs} * 7.20\text{E}+06 \text{ lbs} &= 2.45\text{E}+03 \text{ lbs} \\ &= 1.22 \text{ tons} \end{aligned}$$

B.55 APPENDIX B REFERENCES

1. Asphalt Roofing Manufacturers Association. Written and verbal communication to E. Paik, Radian Corporation. Asphalt roofing product manufactured in the United States in 1993. October 25, 1994.

2. Berenyi, Eileen B. "Methane Recovery from Landfills Makes a Comeback." In: Waste Age, Volume 25, No. 9, pp. 107-114. September 1994.

3. Telephone conversation between Conrad Chin, U.S. EPA and Eric Goehl, Radian Corporation. U.S. EPA MACT background information: U.S. Ferroalloy production levels - 1991. October 31, 1994.

4. Telephone conversation between Rick Copeland, U.S. EPA and Jack Johnson, Eastern Research Group, Inc. Medical waste incinerator data. January 7, 1997.

5. Cremation Association of North America (CANA). Cremation Statistics from Cremationist Journal. Compiled by CANA. 1992.

6. Dempsey, C.R., and E.T. Oppelt. "Incineration of Hazardous Waste: A Critical Review Update." In: Air and Waste, 43:25-73. 1993.

7. Energy Information Administration. "Coke Plant Report-Quarterly." Form EIA-5. Coke and Breeze Production at Coke Plants. 1990 Year End Estimates. Washington, D.C. 1990.

8. Energy Information Administration. Estimate of U.S. Biofuels Consumption 1990. U.S. Department of Energy Office of Coal, Nuclear, Electric, and Alternative Fuels, Washington, DC. p. 6. DOE/EIA-0548(90). 1991.

9. Energy Information Administration. State Energy Data Report, Consumption Estimates 1960-1990. Office of Energy Markets and End Use, Washington, DC. DOE/EIA-0214(90). May 1992.

10. Federal Aviation Administration (FAA). FAA Air Traffic Activity. Office of Management Systems, Washington, DC. p. 1. 1990.

11. Fruh, Steve, U.S. EPA, Data and calculations provided to Jack Johnson, Eastern Research Group, Inc. on 1990 emissions from the Primary Aluminum Industry. January 7, 1997.

12. Hall, Robert E., and Daryl G. DeAngelis. "EPA's Research Program for Controlling Residential Wood Combustion Emissions." Journal of the Air Pollution Control Association, Volume 30, No. 8, pp.862-865. 1980.

13. Lemieux, Paul M., and Jeffery V. Ryan. "Characterization of Air Pollutants Emitted from a Simulated Scrap Tire Fire." In: Journal of the Air and Waste Management Association, Volume 43, pp. 1106-1115. August 1993.

14. Mannsville Chemical Products Corporation. "Naphthalene." In: Chemical Products Synopsis, Asbury Park, New Jersey. March 1993.

15. Memorandum from Cole, J.D., Research Triangle Institute, to William Maxwell, U.S. Environmental Protection Agency. HAP Emission Factors. January 19, 1995.

16. Memorandum from Heath, E., Research Triangle Institute, to J. Wood, U.S. EPA, "Dioxin/Furan Toxic Equivalent Emissions from Cement Kilns that do not Burn Hazardous Waste. March 18, 1996a.

17. Memorandum from Heath, E., Research Triangle Institute, to J. Wood, U.S. EPA, "Dioxin/Furan Toxic Equivalent Emissions from Cement Kilns that Burn Hazardous Waste. March 18, 1996b.

18. Memorandum from LaFlam, G. and T. Johnson, Pacific Environmental Services (PES) to S. Shedd, U.S. EPA Office of Air Quality Planning and Standards. "Speciated Hazardous Air Pollutants-Baseline Emissions and Emission Reductions Under the Gasoline Distribution NESHAP." August 9, 1996.

19. Letter and attachments from Menotti, David, Shaw, Pittman, Potts, and Trowbridge to Anne Pope, U.S. EPA. Comments to the draft 112(c)(6) emission inventory report. November 27, 1996.

20. Micklewright, James T. Wood Preservation Statistics 1993-A Report to the Wood Preserving Industry in the United States. James T. Micklewright, Consulting Forest Product Technologists. May 1994.

21. National Asphalt Pavement Association. "Hot Mix Asphalt Est." George Goggin. 1993.

22. National Council of the Paper Industry for Air and Stream Improvement (NCASI), Inc. Compilaton of Air Toxic Emission Data for Boilers, Pulp Mills, and Bleach Plants. Technical Bulletin No. 650. New York, New York. June 1993.

23. Oil and Gas Journal, Volume 89, No. 11, p. 86. March 18, 1991.

24. Pacific Environmental Services, Inc. Ferroalloy Test Report Furnace No. 5 Globe Metallurgical, Inc. Beverly, Ohio. Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. EMC Report 95-FEA-1. September 1995.

25. Peterson, J. Mt. Baker-Snoqualmie National Forest, and D. Ward, Forest Service Fire Lab. An Inventory of Particulate Matter and Air Toxic Emissions from Prescribed Fires in the United States for 1989. Final Report. IAG DW12934736-01-0-1989. 1993.

26. Plunkert, Patricia A., and Errol D. Sehnke. "Aluminum, Bauxite, and Alumina." In: Minerals Yearbook 1990, U.S. Department of the Interior. p. 132.

27. SRI International. 1993 SRI Directory of Chemical Producers - United States of America. Menlo Park, California. p. 509. 1993.

28. U.S. Department of Agriculture. 1993.

29. U.S. Department of Energy (DOE), Energy Information Administration, 1993a. Household Energy Consumption and Expenditures 1990a. DOE/EIA-0321(90).

30. U.S. Department of Energy (DOE), Energy Information Administration, 1993b. Household Energy Consumption and Expenditures 1990, Supplement, DOE/EIA-0321(90S).

31. U.S. Department of The Interior. Mineral Commodity Summaries. Bureau of Mines, Washington, DC. 1991.

32. U.S. Department of Transportation. Highway Statistics 1990. Federal Highway Administration, Office of Highway Information Management. FHWA-PL-91-003. Washington, D.C. 1990.

33. U.S. Forest Service. 1984-1990 Forest Fire Statistic. U.S. Department of Agriculture-Forest Service. 1993.

34. U.S. Environmental Protection Agency. A Review of Standards of Performance for New Stationary Sources-Ferroalloy Production Facilities. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. EPA-450-3-80-041. December 1980a.

35. U.S. Environmental Protection Agency. Asphalt Roofing Manufacturing-Background Information for Proposed Standards. EPA Report No. EPA-450/3-80-021a. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. 1980b.

36. U.S. Environmental Protection Agency. Coke Oven Emissions from Wet-Coal Charged Byproduct Coke Oven Batteries-Background Information for Proposed Standards. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-450/3-85-028a. April 1987.

37. U.S. Environmental Protection Agency. Technical Guidance-Stage II Vapor Recovery Systems for Control of Vehicle Refueling at Gasoline Dispensing Facilities. EPA Report No. EPA-450/3-91-022a. Research Triangle Park, North Carolina. November 1991.

38. U.S. Environmental Protection Agency. Summary of Markets for Scrap Tires. EPA Report No. EPA/530-SW-90-074b. Office of Solid Waste, Washington, D.C. 1992a.

39. U.S. Environmental Protection Agency. Characterization of Municipal Solid Waste in the United States: 1992 Update. Office of Solid Waste and Emergency Response. EPA/530-R-92-019. p. ES-5. July 1992b.

40. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors-AP-42, Draft Section 12.2-Coke Production. Research Triangle Park, North Carolina. July, 1996c.

41. U.S. Environmental Protection Agency. Emission Factor Documentation for AP-42 Section 1.11, Waste Oil Combustion. Technical Support Division, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. April 1993a.

42. U.S. Environmental Protection Agency. Pulp, Paper, and Paperboard Industry -- Background Information for Proposed Air Emission Standards. Manufacturing Processes at Kraft, Sulfite, Soda, and Semi-Chemical Mills. Emission Standards Division, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-453/R-93-050a. Emission Standards Division, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-450/3-86-010a. October 1993b.

43. U.S. Environmental Protection Agency. Estimating Exposures to Dioxin-like Compounds - Volume II: Properties, Sources, and Occurrence and Background Exposures, External Review Draft. EPA-600/6-88-005Cb. Office of Health and Environmental Assessment, Washington, DC. June 1994a.

44. U.S. Environmental Protection Agency. Gasoline Distribution Industry (Stage I) - Background Information Document for Proposed Standards. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-453/R-94-002a. January, 1994b.

45. U.S. Environmental Protection Agency. Gasoline Distribution Industry (Stage I) - Background Information for Promulgated Standards. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA Report No. EPA-453/R-94-002b. November, 1994c.

46. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. Fifth Edition. Section 1.10. Residential Woodstoves. Research Triangle Park, North Carolina. January 1995.

47. U.S. Environmental Protection Agency. Locating and Estimating Air Emissions from Sources of Polycyclic Organic Matter (POM). Research Triangle Park, North Carolina. September 1996a.

48. U.S. Environmental Protection Agency, Primary Aluminum Industry: Technical Support Document for Proposed MACT Standards. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. July 1996b.

49. Zannes, Maria. Integrated Waste Services Association, letter and attachments to Dennis Beauregard, U.S. Environmental Protection Agency. February 16, 1996.